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INTERNATIONAL STANDARD

Information technology – Generic cabling for customer premises

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Information technology – Generic cabling for customer premises

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FOREWORD

1) ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards. Their preparation is entrusted to technical committees; any ISO and IEC member body interested in the subject dealt with may participate in this preparatory work. International governmental and non-governmental organizations liaising with ISO and IEC also participate in this preparation.

2) In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

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10) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

International Standard ISO/IEC 11801 was prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

This consolidated version of ISO/IEC 11801 consists of the second edition (2002), its Amendment 1 (2008), its Corrigenda 1 (September 2002) and 2 (December 2002) and its Amendment 2 (2010).

The technical content is therefore identical to the base edition and its amendments and has been prepared for user convenience.

It bears the edition number 2.2.

Exceptionally, this consolidated version gives no indication where the contents of the base publication has been modified by amendments.

The significant changes with respect to the first edition and its amendments are listed in Annex H.

This International Standard has taken into account requirements specified in application standards listed in Annex F. It refers to International Standards for components and test methods whenever appropriate International Standards are available.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

This International Standard has been approved by vote of the member bodies, and the voting results for both the base publication and its amendments may be obtained from the address given on the second title page.

INTRODUCTION

Within customer premises, the importance of the cabling infrastructure is similar to that of other fundamental building utilities such as heating, lighting and mains power. As with other utilities, interruptions to service can have a serious impact. Poor quality of service due to lack of design foresight, use of inappropriate components, incorrect installation, poor administration or inadequate support can threaten an organisation's effectiveness.

Historically, the cabling within premises comprised both application specific and multipurpose networks. The original edition of this standard enabled a controlled migration to generic cabling and the reduction in the use of application-specific cabling.

The subsequent growth of generic cabling designed in accordance with ISO/IEC 11801 has

a) contributed to the economy and growth of Information and Communications Technology (ICT),

b) supported the development of high data rate applications based upon a defined cabling model, and

c) initiated development of cabling with a performance surpassing the performance classes specified in ISO/IEC 11801:1995 and ISO/IEC 11801 Ed1.2:2000.

NOTE ISO/IEC 11801, edition 1.2 consists of edition 1.0 (1995) and its amendments 1 (1999) and 2 (1999).

This second edition of ISO/IEC 11801 has been developed to reflect these increased demands and opportunities.

This International Standard provides:

a) users with an application independent generic cabling system capable of supporting a wide range of applications;

b) users with a flexible cabling scheme such that modifications are both easy and economical;

c) building professionals (for example, architects) with guidance allowing the accommodation of cabling before specific requirements are known; that is, in the initial planning either for construction or refurbishment;

d) industry and applications standardization bodies with a cabling system which supports current products and provides a basis for future product development.

This International Standard specifies a multi-vendor cabling system which may be implemented with material from single and multiple sources, and is related to:

a) international standards for cabling components developed by committees of the IEC, for example copper cables and connectors as well as optical fibre cables and connectors (see Clause 2 and bibliography);

b) standards for the installation and operation of information technology cabling as well as for the testing of installed cabling (see Clause 2 and bibliography);

c) applications developed by technical committees of the IEC, by subcommittees of ISO/IEC JTC 1 and by study groups of ITU-T, for example for LANs and ISDN;

d) planning and installation guides which take into account the needs of specific applications for the configuration and the use of cabling systems on customer premises(ISO/IEC 14709 series).

Physical layer requirements for the applications listed in Annex F have been analysed to determine their compatibility with cabling classes specified in this standard. These application requirements, together with statistics concerning the topology of premises and the model described in 7.2, have been used to develop the requirements for Classes A to D and the optical class cabling systems. New Classes E and F have been developed in anticipation of future network technologies.

As a result, generic cabling defined within this International Standard

a) specifies a cabling structure supporting a wide variety of applications,

b) specifies channel and link Classes A, B, C, D and E meeting the requirements of standardised applications,

c) specifies channel and link Classes E and F based on higher performance components to support the development and implementation of future applications,

d) specifies optical channel and link Classes OF-300, OF-500, and OF-2000 meeting the requirements of standardised applications and exploiting component capabilities to ease the implementation of applications developed in the future,

e) invokes component requirements and specifies cabling implementations that ensure performance of permanent links and of channels that meet or exceed the requirements for cabling classes,

f) is targeted at, but not limited to, the general office environment.

This International Standard specifies a generic cabling system that is anticipated to have a usable life in excess of 10 years.

INTRODUCTION to Amendment 1

This amendment provides requirements for new Class E_A and F_A channels plus additions and corrections to ISO/IEC 11801:2002. Amendment 2 of ISO/IEC 11801:2002 will provide balanced cabling models, requirements and normative references for Category 6_A and 7_A components, requirements for Class E_A and F_A links, together with amendments to the requirements for optical fibre cabling.

INTRODUCTION to Amendment 2

Amendment 2 of ISO/IEC 11801:2002 provides balanced cabling models, requirements and normative references for Category 6_A and Category 7_A components, requirements for Class E_A and Class F_A links, together with amendments to the requirements for optical fibre cabling.

INFORMATION TECHNOLOGY – GENERIC CABLING FOR CUSTOMER PREMISES

1 Scope

ISO/IEC 11801 specifies generic cabling for use within premises, which may comprise single or multiple buildings on a campus. It covers balanced cabling and optical fibre cabling.

ISO/IEC 11801 is optimised for premises in which the maximum distance over which telecommunications services can be distributed is 2 000 m. The principles of this International Standard may be applied to larger installations.

Cabling defined by this standard supports a wide range of services, including voice, data, text, image and video.

This International Standard specifies directly or via reference the:

a) structure and minimum configuration for generic cabling,

b) interfaces at the telecommunications outlet (TO),

c) performance requirements for individual cabling links and channels,

d) implementation requirements and options,

e) performance requirements for cabling components required for the maximum distances specified in this standard,

f) conformance requirements and verification procedures.

Safety (electrical safety and protection, fire, etc.) and Electromagnetic Compatibility (EMC) requirements are outside the scope of this International Standard, and are covered by other standards and by regulations. However, information given by this standard may be of assistance.

ISO/IEC 11801 has taken into account requirements specified in application standards listed in Annex F. It refers to available International Standards for components and test methods where appropriate.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

The provisions of the referenced specifications other than ISO/IEC, IEC, ISO and ITU documents, as identified in this clause, are valid within the context of this International Standard. The reference to such a specification within this International Standard does not give it any further status within ISO or IEC. In particular, it does not give the referenced specification the status of an International Standard.

IEC 60352 (all parts), *Solderless connections*

IEC 60352-3, *Solderless connections – Part 3: Solderless accessible insulation displacement connections – General requirements, test methods and practical guidance*

IEC 60352-4, *Solderless connections – Part 4: Solderless non-accessible insulation displacement connections – General requirements, test methods and practical guidance*

IEC 60352-5, *Solderless connections – Part 5: Press-in connections – General requirements, test methods and practical guidance*

IEC 60352-6, *Solderless connections – Part 6: Insulation piercing connections – General requirements, test methods and practical guidance*

IEC 60352-7, *Solderless connections – Part 7: Spring clamp connections – General requirements, test methods and practical guidance*

IEC 60352-8, *Solderless connections – Part 8: Compression mount connections – General requirements, test methods and practical guidance*

IEC 60364-1, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC 60512-2-1, *Connectors for electronic equipment – Tests and measurements – Part 2-1: Electrical continuity and contact resistance tests – Test 2a: Contact resistance – Millivolt level method*

IEC 60512-3-1, *Connectors for electronic equipment – Tests and measurements – Part 3-1: Insulation tests – Test 3a: Insulation resistance*

IEC 60512-4-1, *Connectors for electronic equipment – Tests and measurements – Part 4-1: Voltage stress tests – Test 4a: Voltage proof*

IEC 60512-5-2, *Connectors for electronic equipment – Tests and measurements – Part 5-2: Current-carrying capacity tests – Test 5b: Current-temperature derating*

IEC 60512-25-1, *Connectors for electronic equipment – Tests and measurements – Part 25-1: Test 25a – Crosstalk ratio*

IEC 60512-25-2:2002, *Connectors for electronic equipment – Tests and measurements – Part 25-2: Test 25b – Attenuation (insertion loss)*

IEC 60512-25-4:2001, *Connectors for electronic equipment – Tests and measurements – Part 25-4: Test 25d – Propagation delay*

IEC 60512-25-5, *Connectors for electronic equipment – Tests and measurements – Part 25-5: Test 25e – Return loss*

IEC 60512-25-9:2008, *Connectors for electronic equipment – Tests and measurements – Part 25-9:* Signal integrity *tests – Test 25i: Alien crosstalk*

IEC 60512-26-100, *Connectors for electronic equipment – Tests and measurements – Part 26-100: Measurement setup, test and reference arrangements and measurements for connectors according to IEC 60603-7 – Tests 26a to 26g*

IEC 60603-7, *Connectors for electronic equipment – Part 7: Detail specification for 8-way, unshielded, free and fixed connectors*

IEC 60603-7-1, *Connectors for electronic equipment – Part 7-1: Detail specification for 8-way, shielded free and fixed connectors*

IEC 60603-7-2:2010, *Connectors for electronic equipment – Part 7-2: Detail specification for 8-way, unshielded, free and fixed connectors, for data transmissions with frequencies up to 100 MHz*

IEC 60603-7-3:2010, *Connectors for electronic equipment – Part 7-3: Detail specification for 8-way, shielded, free and fixed connectors, for data transmissions with frequencies up to 100 MHz*

IEC 60603-7-4:2010, *Connectors for electronic equipment – Part 7-4: Detail specification for 8-way, unshielded, free and fixed connectors, for data transmissions with frequencies up to 250 MHz*

IEC 60603-7-5:2010, *Connectors for electronic equipment – Part 7-5: Detail specification for 8-way, shielded, free and fixed connectors, for data transmissions with frequencies up to 250 MHz*

IEC 60603-7-41:2010, *Connectors for electronic equipment – Part 7-41: Detail specification for 8-way, unshielded, free and fixed connectors, for data transmissions with frequencies up to 500 MHz*

IEC 60603-7-51:2010, *Connectors for electronic equipment – Part 7-51: Detail specification for 8-way, shielded, free and fixed connectors, for data transmissions with frequencies up to 500 MHz*

IEC 60603-7-7:–, *Connectors for electronic equipment – Part 7-7: Detail specification for 8-way, shielded, free and fixed connectors, for data transmission with frequencies up to 600 MHz*

IEC 60603-7-71:–, *Connectors for electronic equipment – Part 7-71: Detail specification for 8-way, shielded, free and fixed connectors, for data transmission with frequencies up to 1 000 MHz*

IEC 60793-1-40, *Optical fibres – Part 1-40: Measurement methods and test procedures – Attenuation*

IEC 60793-1-44, *Optical fibres – Part 1-44: Measurement methods and test procedures – Cut-off wavelength*

IEC 60793-1-49, *Optical fibres – Part 1-49: Measurement methods and test procedures – Differential mode delay*

IEC 60793-2:2007, *Optical fibres – Part 2: Product specifications – General*

IEC 60793-2-10, *Optical fibres – Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres*

IEC 60793-2-50, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*

IEC 60794 (all parts), *Optical fibre cables*

IEC 60794-2, *Optical fibre cables – Part 2: Indoor cables – Sectional specification*

IEC 60825 (all parts), *Safety of laser products*

IEC 60874-19-1:2007, *Fibre optic interconnecting devices and passive components Connectors for optical fibres and cables – Part 19-1: Fibre optic patch cord connector type SC-PC (floating duplex) standard terminated on multimode fibre type A1a, A1b – Detail specification*

IEC 60874-19-2:1999, *Connectors for optical fibres and cables – Part 19-2: Fibre optic adaptor (duplex) type SC for single-mode fibre connectors – Detail specification*

IEC 60874-19-3:2007, *Fibre optic interconnecting devices and passive components – Connectors for optical fibres and cables – Part 19-3 Fibre optic adaptor (duplex) type SC for multimode fibre connectors – Detail specification*

IEC 61073-1, *Fibre optic interconnecting devices and passive components – Mechanical splices and fusion splice protectors for optical fibres and cables – Part 1: Generic specification*

IEC 61076-3-104, *Connectors for electronic equipment – Part 3-104: Detail specification for 8-way, shielded free and fixed connectors for data transmissions with frequencies up to 1 000 MHz*

IEC 61076-3-110, *Connectors for electronic equipment – Part 3-110: Detail specification for shielded, free and fixed connectors for data transmission with frequencies up to 1 000 MHz*

IEC 61156 (all parts), *Multicore and symmetrical pair/quad cables for digital communications*

IEC 61156-1:2007, *Multicore and symmetrical pair/quad cables for digital communications – Part 1: Generic specification*
Amendment 1 (2009)

IEC 61156-2:2010, *Multicore and symmetrical pair/quad cables for digital communications – Part 2: Symmetrical pair/quad cables with transmission characteristics up to 100 MHz – Horizontal floor cable – Sectional specification*

IEC 61156-3:2008, *Multicore and symmetrical pair/quad cables for digital communications – Part 3: Work area wiring – Sectional specification*

IEC 61156-4:2009, *Multicore and symmetrical pair/quad cables for digital communications – Part 4: Riser cables – Sectional specification*

IEC 61156-5:2009, *Multicore and symmetrical pair/quad cables for digital communications – Part 5: Symmetrical pair/quad cables with transmission characteristics up to 1 000 MHz – Horizontal floor wiring – Sectional specification*

IEC 61156-6:2010, *Multicore and symmetrical pair/quad cables for digital communications – Part 6: Symmetrical pair/quad cables with transmission characteristics up to 1 000 MHz – Work area wiring – Sectional specification*

IEC 61300-1, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 1: General and guidance*

IEC 61300-2-2:1995, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-2: Tests – Mating durability*

IEC 61300-3-6:1997, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-6: Examinations and measurements – Return loss*
Amendment 1:1998

Amendment 2:1999

IEC 61300-3-34:2001, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-34: Examinations and measurements – Attenuation of random mated connectors*

IEC 61754-20:2002, *Fibre optic connector interfaces – Part 20: Type LC connector family*

IEC 61935-1, *Specification for the testing of balanced communication cabling in accordance with ISO/IEC 11801 – Part 1: Installed cabling*

IEC 61935-2, *Testing of balanced communication cabling in accorance with ISO/IEC 11801 – Part 2: Patch cords and work area cords*

IEC 62153-4-12, *Metallic communication cable test methods – Part 4-12: Electromagnetic compatibility (EMC) – Coupling attenuation or screened attenuation of connecting hardware – Absorbing clamp method*

ISO/IEC 14763-1, *Information technology – Implementation and operation of customer premises cabling – Part 1: Administration*

ISO/IEC TR 14763-2:2000, *Information technology – Implementation and operation of customer premises cabling – Part 2: Planning and installation*

ISO/IEC 14763-3, *Information technology – Implementation and operation of customer premises cabling – Part 3: Testing of optical fibre cabling*

ISO/IEC 15018, *Information technology – Generic cabling for homes*

ISO/IEC 18010, *Information technology – Pathways and spaces for customer premises cabling*

ISO/IEC TR 24750:2007, *Information technology – Assessment and mitigation of installed balanced cabling channels in order to suport 10GBASE-T*

ITU-T Recommendation O.9: *Measuring arrangements to assess the degree of unbalance about earth*

3 Terms, definitions, abbreviations and symbols

3.1 Terms and definitions

For the purposes of this International Standard, the following definitions apply.

NOTE The abbreviation "lg" in the equations signifies "$\log_{10}$".

3.1.1
administration
methodology defining the documentation requirements of a cabling system and its containment, the labelling of functional elements and the process by which moves, additions and changes are recorded

3.1.2
alien (exogenous) crosstalk
signal coupling from a disturbing pair of a channel to a disturbed pair of another channel

NOTE This also applies to the signal coupling from a disturbing pair within a permanent link or component, used to create a channel, to a disturbed pair within a permanent link or component, used to create another channel.

3.1.3
alien (exogenous) far-end crosstalk loss (AFEXT)
signal isolation between a disturbing pair of a channel and a disturbed pair of another channel, measured at the far-end

NOTE This also applies to the measurement of the signal isolation between a disturbing pair within a permanent link or component, used to create a channel, and a disturbed pair within a permanent link or component, used to create another channel.

3.1.4
alien (exogenous) near-end crosstalk loss (ANEXT)
signal isolation between a disturbing pair of a channel and a disturbed pair of another channel, measured at the near-end

NOTE This also applies to the measurement of signal isolation between a disturbing pair within a permanent link or component, used to create a channel, and a disturbed pair within a permanent link or component, used to create another channel.

3.1.5
application
system, including its associated transmission method, which is supported by telecommunications cabling

3.1.6
attenuation
decrease in magnitude of power of a signal in transmission between points

NOTE Attenuation indicates the total losses on cable, expressed as the ratio of power output to power input.

3.1.7
attenuation to alien (exogenous) crosstalk ratio at the far-end (AACR-F)
difference, in dB, between the alien far-end crosstalk loss from a disturbing pair of a channel and the insertion loss of a disturbed pair in another channel

NOTE This also applies to the calculation using the alien far-end crosstalk loss from a disturbing pair within a permanent link or component, used to create a channel, and the insertion of a disturbed pair within a permanent link or component, used to create another channel.

3.1.8
attenuation to alien (exogenous) crosstalk ratio at the near-end (AACR-N)
difference, in dB, between the alien near-end crosstalk loss from a disturbing pair of a channel and the insertion loss of a disturbed pair in another channel

NOTE This also applies to the calculation using the alien near-end crosstalk loss from a disturbing pair within a permanent link or component, used to create a channel, and the insertion loss of a disturbed pair within a permanent link or component, used to create another channel.

3.1.9
attenuation to crosstalk ratio at the far-end (ACR-F)
difference, in dB, between the far-end crosstalk loss from a disturbing pair of a channel and the insertion loss of a disturbed pair of the same channel

NOTE This also applies to the calculation using the far-end crosstalk loss from a disturbing pair within a permanent link or component, used to create a channel, and the insertion loss of a disturbed pair within the permanent link or component, of the same channel.

3.1.10
attenuation to crosstalk ratio at the near-end (ACR-N)
difference, in dB, between the near-end crosstalk loss from a disturbing pair of a channel and the insertion loss of a disturbed pair of the same channel

NOTE This also applies to the calculation using the near-end crosstalk loss from a disturbing pair within a permanent link or component, used to create a channel, and the insertion loss of a disturbed pair within the permanent link or component, of the same channel.

3.1.11
average power sum alien (exogenous) near-end crosstalk loss
the calculated average of the power sum alien near-end crosstalk loss of the pairs of a disturbed channel

NOTE This also applies to the calculation using the pairs within a permanent link used to create a channel.

3.1.12
average power sum attenuation to alien (exogenous) crosstalk ratio far-end
the calculated average of the power sum attenuation to alien crosstalk ratio at the far-end of the pairs of a disturbed channel

NOTE This also applies to the calculation using the pairs within a permanent link used to create a channel.

3.1.13
balanced cable
cable consisting of one or more metallic symmetrical cable elements (twisted pairs or quads)

3.1.14
building backbone cable
cable that connects the building distributor to a floor distributor

NOTE Building backbone cables may also connect floor distributors in the same building.

3.1.15
building distributor
distributor in which the building backbone cable(s) terminate(s) and at which connections to the campus backbone cable(s) may be made

3.1.16
building entrance facility
facility that provides all necessary mechanical and electrical servicesand which complies with all relevant regulations, for the entry of telecommunications cables into a building

3.1.17
cable
assembly of one or more cable units of the same type and category in an overall sheath

NOTE The assembly may include an overall screen.

3.1.18
cable element
smallest construction unit (for example pair, quad or single fibre) in a cable

NOTE A cable element may have a screen.

3.1.19
cable unit
single assembly of one or more cable elements of the same type or category

NOTE 1 The cable unit may have a screen.
NOTE 2 A binder group is an example of a cable unit.

3.1.20
cabled optical fibre category
system of defining requirements for the cabled optical fibre performance within optical fibre cabling channels and links

NOTE Also referred to as performance codes in some standards.[1]

3.1.21
cabling
system of telecommunications cables, cords and connecting hardware that can support the connection of information technology equipment

3.1.22
campus
premise containing one or more buildings

3.1.23
campus backbone cable
cable that connects the campus distributor to the building distributor(s)

NOTE Campus backbone cables may also connect building distributors directly.

3.1.24
campus distributor
distributor from which the campus backbone cabling starts

3.1.25
channel
end-to-end transmission path connecting any two pieces of application specific equipment

NOTE Equipment and work area cords are included in the channel, but not the connecting hardware into the application specific equipment.

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1 Standards developed by IEC subcommittee 86C use this definition in support of JTC 1/SC25 standards.

3.1.26
centralised optical fibre cabling
centralised optical fibre cabling techniques create a combined backbone/horizontal channel; this channel is provided from the work areas to the centralised cross-connect or interconnect by allowing the use of pull-through cables or splices

3.1.27
connecting hardware
connecting hardware is considered to consist of a device or a combination of devices used to connect cables or cable elements

3.1.28
connection
mated device or combination of devices including terminations used to connect cables or cable elements to other cables, cable elements or application specific equipment

3.1.29
consolidation point (CP)
connection point in the horizontal cabling subsystem between a floor distributor and a telecommunications outlet

3.1.30
cord
cable, cable unit or cable element with a minimum of one termination

3.1.31
coupling attenuation
coupling attenuation is the relation between the transmitted power through the conductors and the maximum radiated peak power, conducted and generated by the excited common mode currents

3.1.32
CP cable
cable connecting the consolidation point to the telecommunications outlet(s)

3.1.33
CP link
part of the permanent link between the floor distributor and the consolidation point, including the connecting hardware at each end

3.1.34
cross-connect
apparatus enabling the termination of cable elements and their cross-connection, primarily by means of patch cords or jumpers

NOTE Incoming and outgoing cables are terminated at fixed points.

3.1.35
distributor
term used for a collection of components (such as patch panels, patch cords) used to connect cables

3.1.36
equal level far-end crosstalk ratio (ELFEXT)
difference, in dB, between the far-end crosstalk loss from a disturbing pair of a channel and the insertion loss of a disturbing pair of the same channel

NOTE This also applies to the calculation using the far-end crosstalk loss from a disturbing pair within a permanent link or component, used to create a channel, and the insertion loss of a disturbing pair within a permanent link or component, of the same channel.

3.1.37
equipment cord
cord connecting equipment to a distributor

3.1.38
equipment interface
location where a connection between equipment and the cabling system occurs

3.1.39
equipment room
room dedicated to housing distributors and application specific equipment

3.1.40
external network interface
point of demarcation between public and private network

NOTE In many cases the external network interface is the point of connection between the network provider's facilities and the customer premises cabling.

3.1.41
fixed horizontal cable
cable connecting the floor distributor to the consolidation point if a CP is present, or to the TO if no CP is present

3.1.42
floor distributor
distributor used to connect between the horizontal cable and other cabling subsystems or equipment

NOTE See also telecommunications room.

3.1.43
generic cabling
structured telecommunications cabling system, capable of supporting a wide range of applications

NOTE Generic cabling can be installed without prior knowledge of the required applications. Application specific hardware is not a part of generic cabling.

3.1.44
horizontal cable
cable connecting the floor distributor to the telecommunications outlet(s)

3.1.45
hybrid cable
assembly of two or more cable units and/or cables of different types or categories in an overall sheath

NOTE The assembly may include an overall screen.

3.1.46
individual work area
minimum building space that would be reserved for an occupant

3.1.47
insertion loss
loss incurred by inserting a device between a source and load of equal impedance. The device itself may have a different impedance from the load and source impedance

NOTE The terms operational attenuation or operational insertion loss are sometimes associated with this definition.

3.1.48
insertion loss deviation
difference between the measured insertion loss of cascaded components and the insertion loss determined by the sum of the individual component insertion losses

3.1.49
interconnect
technique enabling equipment cords (or cabling subsystems) to be terminated and connected to the cabling subsystems without using a patch cord or jumper

NOTE Incoming or outgoing cables are terminated at a fixed point.

3.1.50
interface
point at which connections are made to the generic cabling

3.1.51
jumper
cable, cable unit or cable element without connectors used to make a connection on a cross-connect

3.1.52
keying
mechanical feature of a connector system, which guarantees polarization or prevents the connection to an incompatible socket or optical fibre adapter

3.1.53
link
transmission path between two cabling system interfaces, including the connections at each end

3.1.54
longitudinal conversion loss
logarithmic ratio expressed in decibels of the common mode injected signal at the near end to the resultant differential signal at the near end of a balanced pair

3.1.55
longitudinal conversion transfer loss
logarithmic ratio expressed in decibels of the common mode injected signal at the near end to the resultant differential signal at the far end of a balanced pair

3.1.56
multi-user telecommunications outlet assembly
grouping in one location of several telecommunications outlets

3.1.57
operating temperature
stabilised temperature of the cabling combining ambient temperature with any increase due to the application being supported

3.1.58
optical fibre cable (or optical cable)
cable comprising one or more optical fibre cable elements

3.1.59
optical fibre duplex adapter
mechanical device designed to align and join two duplex connectors

3.1.60
optical fibre duplex connector
mechanical termination device designed to transfer optical power between two pairs of optical fibres

3.1.61
overfilled launch
controlled launch where the test fibre is overfilled with respect to both angle and position to simulate LED launches

3.1.62
pair
two conductors of a balanced transmission line. It generally refers to a twisted-pair or one side circuit

3.1.63
patch cord
cable, cable unit or cable element with connector(s) used to establish connections on a patch panel

3.1.64
patch panel
assembly of multiple connectors designed to accommodate the use of patch cords

NOTE The patch panel facilitates administration for moves and changes.

3.1.65
permanent link
transmission path between the telecommunications outlet and the floor distributor

NOTE The permanent link does not include work area cords, equipment cords, patch cords and jumpers, but includes the connection at each end. It can include a CP link.

3.1.66
power sum alien (exogenous) far-end crosstalk loss (PS AFEXT)
power sum of the signal isolation between multiple disturbing pairs of one or more channels and a disturbed pair of another channel, measured at the far-end

NOTE This also applies to the calculation using the multiple disturbing pairs within one or more permanent links or components and a disturbed pair within a permanent link or component, used to create another channel.

3.1.67
power sum alien (exogenous) near-end crosstalk loss (PS ANEXT)
power sum of the signal isolation between multiple disturbing pairs of one or more channels and a disturbed pair of another channel, measured at the near-end

NOTE This also applies to the calculation using the multiple disturbing pairs within one or more permanent links or components and a disturbed pair within a permanent link or component, used to create another channel.

3.1.68
power sum attenuation to alien (exogenous) crosstalk ratio at the far-end (PS AACR-F)
difference, in dB, between the power sum alien far-end crosstalk loss from multiple disturbing pairs of one or more channels and the insertion loss of a disturbed pair in another channel

NOTE This also applies to the calculation using the power sum alien far-end crosstalk loss from multiple disturbing pairs within one or more permanent links or components and the insertion loss of a disturbed pair within a permanent link or component, used to create another channel.

3.1.69
power sum attenuation to alien (exogenous) crosstalk ratio at the near-end (PS AACR-N)
difference, in dB, between the power sum alien near-end crosstalk loss from multiple disturbing pairs of one or more channels and the insertion loss of a disturbed pair in another channel

NOTE This also applies to the calculation using the power sum alien near-end crosstalk loss from multiple disturbing pairs within one or more permanent links or components, and the insertion loss of a disturbed pair within a permanent link or component, used to create another channel.

3.1.70
power sum attenuation to crosstalk ratio at the far-end (PS ACR-F)
difference, in dB, between the power sum far-end crosstalk loss from multiple disturbing pairs of a channel and the insertion loss of a disturbed pair in the same channel

NOTE This also applies to the calculation using the power sum far-end crosstalk loss from multiple disturbing pairs within one or more permanent links or components, used to create a channel, and the insertion loss of a disturbed pair within a permanent link or component, of the same channel.

3.1.71
power sum attenuation to crosstalk ratio at the near-end (PS ACR-N)
difference, in dB, between the power sum near-end crosstalk loss from multiple disturbing pairs of a channel and the insertion loss of a disturbed pair in the same channel

NOTE This also applies to the calculation using the multiple disturbing pairs within one or more permanent links or components, used to create a channel, and the insertion loss of a disturbed pair within a permanent link or component, of the same channel.

3.1.72
power sum equal level far-end crosstalk ratio (PS ELFEXT)
power sum of all disturbing pairs of a channel, of the difference, in dB, between the far-end crosstalk loss and the insertion loss of each disturbing pair

NOTE This also applies to the calculation using the multiple disturbing pairs within one or more permanent links or components, used to create a channel, and the insertion loss of a disturbing pair within a permanent link or component, of the same channel.

3.1.73
quad
cable element that comprises four insulated conductors twisted together

NOTE Two diametrically facing conductors form a transmission pair.

3.1.74
screened balanced cable
balanced cable with an overall screen and/or screens for the individual elements

3.1.75
side circuit
two diametrically facing conductors in a quad that form a pair

3.1.76
small form factor connector
optical fibre connector designed to accommodate two or more optical fibres with at least the same mounting density as achievable within the IEC 60603-7 series

3.1.77
splice
joining of conductors or optical fibres, generally from separate sheaths

3.1.78
telecommunications
branch of technology concerned with the transmission, emission and reception of signs, signals, writing, images and sounds, that is, information of any nature by cable, radio, optical or other electromagnetic systems

NOTE The term telecommunications has no legal meaning when used in this International Standard.

3.1.79
telecommunications room
enclosed space for housing telecommunications equipment, cable terminations, interconnect and cross-connect

3.1.80
telecommunications outlet
fixed connecting device where the horizontal cable terminates

NOTE The telecommunications outlet provides the interface to the work area cabling.

3.1.81
test interface
location where a connection between test equipment and the cabling to be tested occurs

3.1.82
transverse conversion loss
ratio between the common mode signal power and the injected differential mode signal power

3.1.83
twisted pair
cable element that consists of two insulated conductors twisted together in a determined fashion to form a balanced transmission line

3.1.84
unscreened balanced cable
balanced cable without any screens

3.1.85
work area
building space where the occupants interact with telecommunications terminal equipment

3.1.86
work area cord
cord connecting the telecommunications outlet to the terminal equipment

3.2 Abbreviations

AACR-F	Attenuation to alien crosstalk ratio at the far-end
a.c.	Alternating current
ACR	Attenuation to crosstalk ratio
ACR-F	Attenuation to crosstalk ratio at the far-end
ACR-N	Attenuation to crosstalk ratio at the near-end
AFEXT	Alien far-end crosstalk (loss)
ANEXT	Alien near-end crosstalk (loss)
APC	Angled physical contact
ATM	Asynchronous transfer mode
BCT	Broadcast and communications technologies, sometimes referred to as HEM
BD	Building distributor
B-ISDN	Broadband ISDN
CD	Campus distributor
CP	Consolidation point
CSMA/CD	Carrier sense multiple access with collision detection
d.c.	Direct current
DCE	Data circuit terminating equipment
DTE	Data terminal equipment
DRL	Distributed return loss
EI	Equipment interface
ELFEXT	Equal level FEXT
ELTCTL	Equal level TCTL

EMC	Electromagnetic compatibility
EQP	Equipment
ER	Equipment room
FD	Floor distributor
FDDI	Fibre distributed data interface
FEXT	Far end crosstalk attenuation (loss)
f.f.s.	For further study
FOIRL	Fibre optic inter-repeater link
HEM	Home Entertainment & Multimedia, see BCT
IC	Integrated circuit
ICT	Information and communications technology
IDC	Insulation displacement connection
IEC	International Electrotechnical Commission
IL	Insertion loss
ILD	Insertion loss deviation
IPC	Insulation piercing connection
ISDN	Integrated services digital network
ISLAN	Integrated services local area network
ISO	International Organization for Standardization
IT	Information technology
JTC	Joint technical committee
LAN	Local area network
LCL	Longitudinal to differential conversion loss
LCTL	Longitudinal to differential conversion transfer loss
Min.	minimum
MUTO	Multi-user telecommunications outlet
N/A	Not applicable
NEXT	Near end crosstalk attenuation (loss)
OF	Optical fibre
OFL	Overfilled launch
PBX	Private branch exchange
PC	Physical contact
PMD	Physical layer media dependent
PS AACR-F	Power sum attenuation to alien crosstalk ratio at the far-end
PS AACR-F_{avg}	Average power sum attenuation to alien crosstalk ratio at the far-end
PS ACR	Power sum ACR
PS ACR-F	Power sum attenuation to crosstalk ratio at the far-end
PS ACR-N	Power sum attenuation to crosstalk ratio at the near-end
PS AFEXT	Power sum alien far-end crosstalk (loss)
PS $AFEXT_{norm}$	Normalized power sum alien far-end crosstalk (loss)
PS ANEXT	Power sum alien near-end crosstalk (loss)
PS $ANEXT_{avg}$	Average power sum alien near-end crosstalk (loss)
PS ELFEXT	Power sum ELFEXT
PS FEXT	Power sum FEXT (loss)
PS NEXT	Power sum NEXT (loss)
PVC	Polyvinyl chloride
RL	Return loss

SC	Subscriber connector (optical fibre connector)
SC-D	Duplex SC connector
SFF	Small form factor connector
TCL	Transverse conversion loss
TCTL	Transverse conversion transfer loss
TE	Terminal equipment
TI	Test interface
TO	Telecommunications outlet
TP-PMD	Twisted pair physical medium dependent

3.3 Symbols

3.3.1 Variables

A	coefficient of transmission matrix
B	length of backbone cable or coefficient of transmission matrix
C	length of the CP cable, designation for connector, or coefficient of transmission matrix
D	coefficient of transmission matrix
F	combined length of patch cords/jumpers, equipment and work area cords
H	maximum length of the fixed horizontal cable
K	coefficient of cable attenuation increase
L	length of cable
l	number of the disturbing channel
N	number of disturbing channels
X	ratio of work area cable attenuation to fixed horizontal cable attenuation
Y	ratio of the CP cable attenuation to the fixed horizontal cable attenuation
Z	complex impedance
DRL_o	constant of the distributed return loss
NVP	velocity relative to speed of light (= v/c)
Z_0	characteristic impedance
Z_{fit}	curve fitted or average impedance
c	speed of light in vacuum
e	base of natural logarithm
f	frequency
i	current number of disturbing pair
j	imaginary operator
k	current number of disturbed pair
n	total number of pairs ($l \leq k \leq n$)
t	time
v	speed of propagation
k_1	constant for the first coefficient of the cable attenuation
k_2	constant for the second coefficient of the cable attenuation

k_3	constant for the third coefficient of the cable attenuation
k_c	constant for the coefficient of the connector insertion loss
ϑ	temperature in °C
ϑ_coeff	temperature coefficient of cable attenuation in %/°C
Φ	phase angle in degrees
α	attenuation
β	phase angle of the propagated signal in rad/m or in radians
γ	complex propagation constant ($\gamma = \alpha + j\beta$)
π	constant

3.3.2 Indices

C2	index to denominate a characteristic, measured from the connector at the floor distributor (second connector)
CH	index to denote the channel
CP	index to denote the consolidation point
PL	index to denominate a permanent link characteristic
TO	index to denominate a characteristic, measured from the TO
avg	index to denominate average of the associated parameter across all of the pairs in the same channel or permanent link
cable	index to denominate a cable characteristic
channel	index to denominate a channel characteristic
connector	index to denominate a connector characteristic
cord cable	index to indicate a characteristic of the cable used for cords
in	index to indicate an input condition
local	index to denominate a locally measured characteristic
norm	index to denominate scaling of the associated parameter
remote	index to denominate a characteristic measured at a distance
term	index to indicate a terminating condition
ϑ	index to denominate a temperature dependent characteristic

4 Conformance

For a cabling installation to conform to this International Standard the following applies.

a) The configuration and structure shall conform to the requirements outlined in Clause 5.

b) The performance of balanced channels shall meet the requirements specified in Clause 6.

This shall be achieved by one of the following:

1) a channel design and implementation ensuring that the prescribed channel performance is met;

2) attachment of appropriate components to a permanent link or CP link design meeting the prescribed performance class of Clause 6 and Annex A. Channel performance shall be ensured where a channel is created by adding more than one cord to either end of a link meeting the requirements of Annex A;

3) using the reference implementations of Clause 7 and compatible cabling components conforming to the requirements of Clauses 9, 10 and 13, based upon a statistical approach of performance modelling.

c) The implementation and performance of optical fibre cabling channels shall meet the requirements specified in Clause 8.

d) The interfaces to the cabling at the TO shall conform to the requirements of Clause 10 with respect to mating interfaces and performance.

e) Connecting hardware at other places in the cabling structure shall meet the performance requirements specified in Clause 10.

f) If present, screens shall be handled as specified in Clause 11.

g) System administration shall meet the requirements of Clause 12.

h) Regulations on safety and EMC applicable at the location of the installation shall be met.

Test methods to assess conformance with the channel and link requirements of Clause 6 and Annex A respectively are specified in IEC 61935-1 for balanced cabling and ISO/IEC 14763-3 for optical fibre cabling. The treatment of measured results that fail to meet the requirements of Clause 6 and Annex A respectively, or lie within the relevant measurement accuracy, shall be clearly documented within a quality plan as described in ISO/IEC 14763-2.

Installation and administration of cabling in accordance with this International Standard shall be undertaken in accordance with ISO/IEC 14763-2.

This International Standard does not specify which tests and sampling levels should be adopted. The test parameters to be measured and the sampling levels to be applied for a particular installation shall be defined in the installation specification and quality plans for that installation prepared in accordance with ISO/IEC 14763-2.

In the absence of the channel, the conformance of the link shall be used to verify conformance with the standard.

Specifications marked "f.f.s." are preliminary specifications, and are not required for conformance to this International Standard.

5 Structure of the generic cabling system

5.1 General

This clause identifies the functional elements of generic cabling, describes how they are connected together to form subsystems and identifies the interfaces at which application-specific components are connected to the generic cabling.

Applications are supported by connecting equipment to the telecommunications outlets and distributors.

5.2 Functional elements

The functional elements of generic cabling are as follows:

- campus distributor (CD);
- campus backbone cable;
- building distributor (BD);

- building backbone cable;
- floor distributor (FD);
- horizontal cable;
- consolidation point (CP);
- consolidation point cable (CP cable);
- multi-user telecommunications outlet (MUTO);
- telecommunications outlet (TO).

Groups of these functional elements are connected together to form cabling subsystems.

5.3 Cabling subsystems

5.3.1 General

Generic cabling systems contain up to three cabling subsystems: campus backbone, building backbone and horizontal cabling. The composition of the subsystems is described in 5.3.2, 5.3.3 and 5.3.4. The cabling subsystems are connected together to create a generic cabling system with a structure as shown in Figure 1. The distributors provide the means to configure the cabling to support different topologies like bus, star and ring.

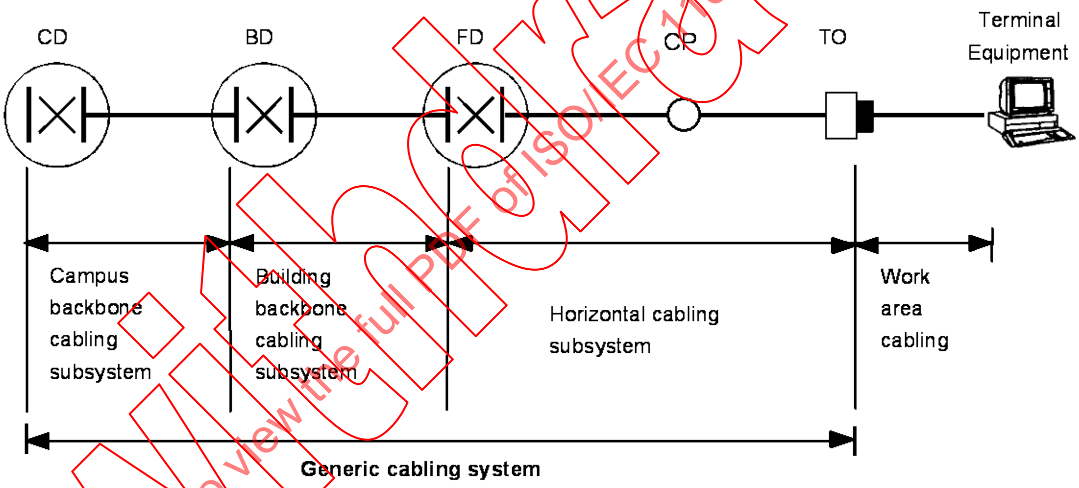


Figure 1 – Structure of generic cabling

Connections between cabling subsystems are either active, requiring application-specific equipment, or passive. Connection to application-specific equipment adopts either an interconnect or a cross-connect approach (see Figure 5 and Figure 6). Passive connections between cabling subsystems are generally achieved using cross-connections by way of either patch cords or jumpers.

In the case of centralised cabling, passive connections in the distributors are achieved by using cross-connections or interconnections. In addition, for centralised optical fibre cabling, it is possible to create connections at the distributors using splices although this reduces the ability of the cabling to support re-configuration.

5.3.2 Campus backbone cabling subsystem

The campus backbone cabling subsystem extends from the campus distributor to the building distributor(s), usually located in separate buildings. When present, the subsystem includes:

- the campus backbone cables;
- any cabling components within the building entrance facilities;
- jumpers and patch cords in the campus distributor;
- the connecting hardware on which the campus backbone cables are terminated (at both the campus and building distributors).

Although equipment cords are used to connect the transmission equipment to the cabling subsystem, they are not considered part of the cabling subsystem because they are application specific. Where the building distributor does not exist, the campus backbone cabling subsystem extends from the campus distributor to the floor distributor. It is possible for campus backbone cabling to provide direct connection between building distributors. When provided, this cabling shall be in addition to that required for the basic hierarchical topology.

5.3.3 Building backbone cabling subsystem

A building backbone cabling subsystem extends from building distributor(s) to the floor distributor(s). When present, the subsystem includes:

- the building backbone cables;
- jumpers and patch cords in the building distributor;
- the connecting hardware on which the building backbone cables are terminated (at both the building and floor distributors).

Although equipment cords are used to connect the transmission equipment to the cabling subsystem, they are not considered part of the cabling subsystem because they are application specific. It is possible for building backbone cabling to provide direct connection between floor distributors. When provided, this cabling shall be in addition to that required for the basic hierarchical topology.

5.3.4 Horizontal cabling subsystem

The horizontal cabling subsystem extends from a floor distributor to the telecommunications outlet(s) connected to it. The subsystem includes:

- the horizontal cables;
- jumpers and patch cords in the floor distributor;
- the mechanical termination of the horizontal cables at the telecommunications outlet;
- the mechanical termination of the horizontal cables at the floor distributor including the connecting hardware, for example of the interconnect or cross-connect;
- a consolidation point (optional);
- the telecommunications outlets.

Although work area and equipment cords are used to connect terminal and transmission equipment respectively to the cabling subsystem, they are not considered part of the cabling subsystem because they are application specific. Horizontal cables shall be continuous from the floor distributor to the telecommunications outlets unless a consolidation point is installed (see 5.7.6).

5.3.5 Design objectives

Horizontal cabling should be designed to support the broadest set of existing and emerging applications and therefore provide the longest operational life. This will minimise disruption and the high cost of recabling in the work area.

Building backbone cabling should be designed for the entire life of the generic cabling system. However, it is common to adopt short-term approaches that support current and foreseeable application requirements, particularly where there is good physical access to pathways. The selection of campus backbone cabling may require a longer-term approach than that adopted for the building backbone, particularly if access to pathways is more limited.

5.4 Interconnection of subsystems

5.4.1 General

In generic cabling, the functional elements of the cabling subsystems are interconnected to form a hierarchical structure as shown in Figure 2 and Figure 3.

Where the functions of distributors are combined (see 5.7.1), the intermediate cabling subsystem is not required.

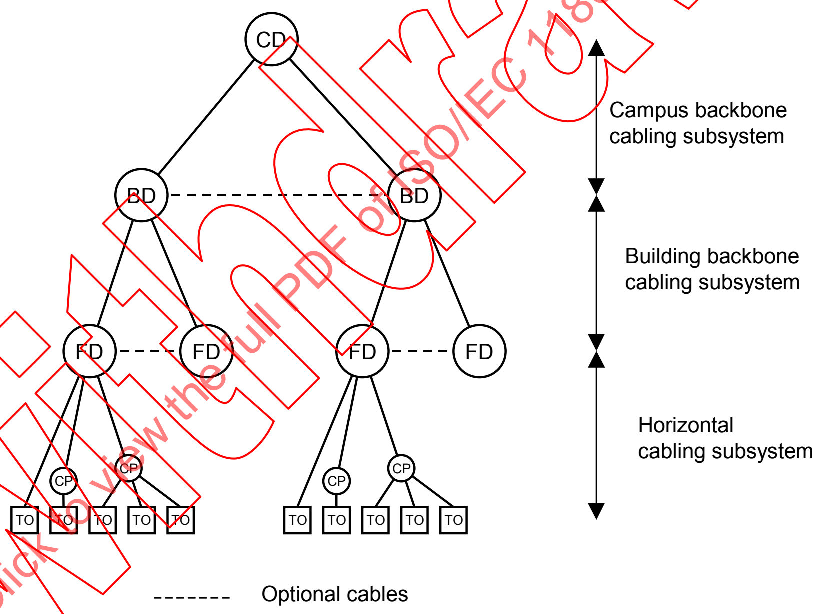


Figure 2 – Hierarchical structure of generic cabling

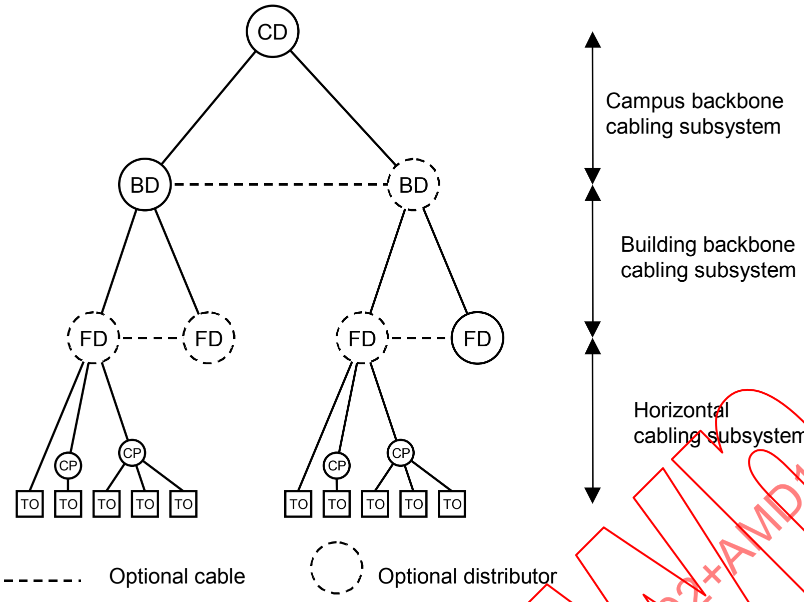


Figure 3 – Structures for centralised generic cabling

5.4.2 Centralised cabling architecture

Centralised cabling structures as shown in Figure 3 create combined backbone/horizontal channels. The channels are provided by passive connections in the distributors. The connections are achieved by using either cross-connections or interconnections. In addition, for centralised optical fibre cabling, it is possible to create connections at the distributors using splices although this reduces the ability of the cabling to support re-configuration.

5.5 Accommodation of functional elements

Figure 4 shows an example of how the functional elements are accommodated in a building.

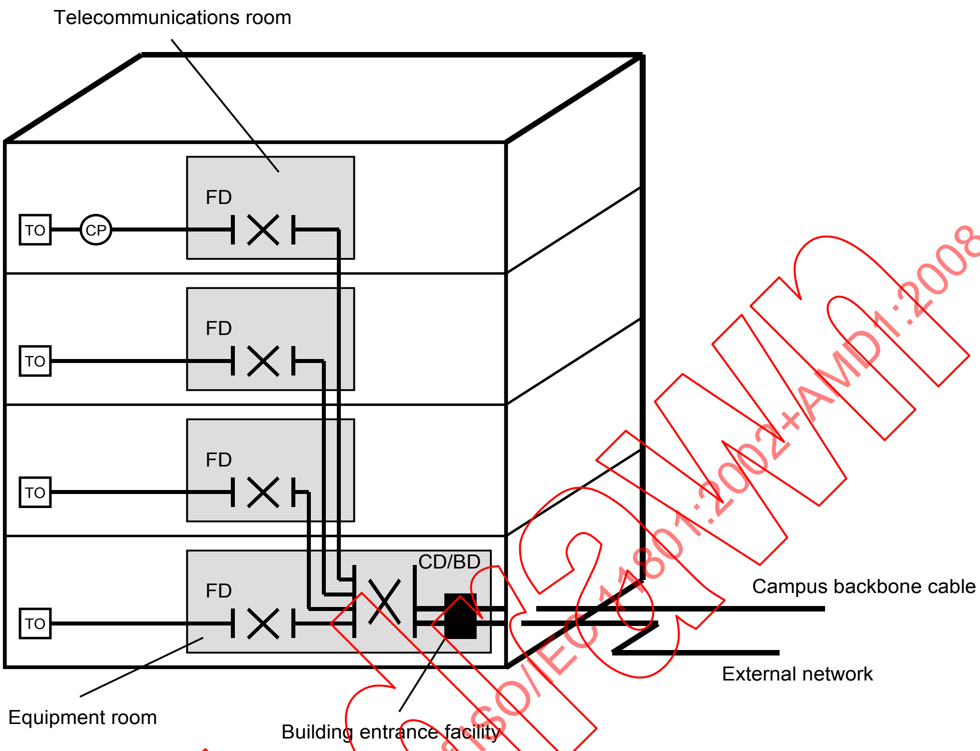


Figure 4 – Accommodation of functional elements

Distributors can be located in equipment rooms or telecommunications rooms. Requirements for the accommodation of distributors are given in ISO/IEC 14763-2 (first edition). Until ISO/IEC 14763-2 is published, relevant information can be found in ISO/IEC TR 14763-2.

Cables are routed using pathways. A variety of cable management systems can be used to support the cables within the pathways including ducts, conduits and trays. Requirements for pathways and cable management systems are provided in ISO/IEC 14763-2 (first edition). Until ISO/IEC 14763-2 is published, relevant information can be found in ISO/IEC 18010. Telecommunications outlets are typically located in the work area.

5.6 Interfaces

5.6.1 Equipment interfaces and test interfaces

Equipment interfaces to generic cabling are located at the ends of each subsystem. Any distributor may have an equipment interface to an external service at any port and may use either interconnects as shown in Figure 5 or cross-connects as shown in Figure 6. The consolidation point does not provide an equipment interface to the generic cabling system. Figure 7 shows the potential equipment interfaces to the horizontal and backbone cabling subsystems.

Test interfaces to generic cabling are located at the ends of each subsystem and at consolidation points, where present. Figure 7 shows the potential test interfaces to the horizontal cabling subsystem.

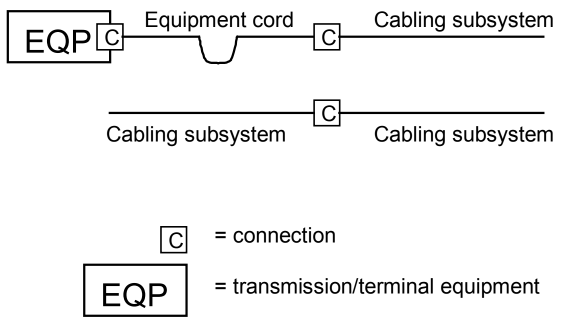


Figure 5 – Interconnect models

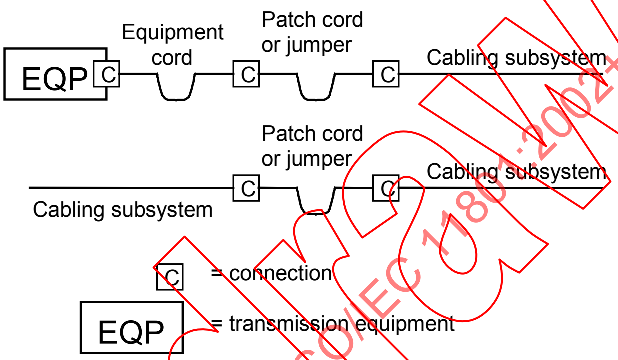
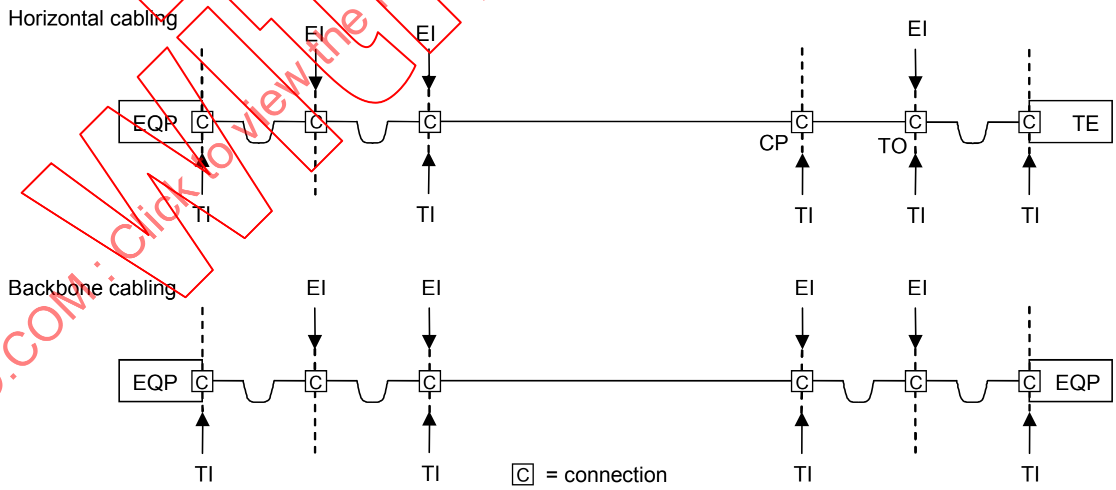


Figure 6 – Cross-connect models



Key

EI Equipment interface

TI Test interface

Figure 7 – Equipment and test interfaces

5.6.2 Channel and permanent link

The transmission performance of generic cabling is detailed in Clauses 6, 8 and Annex A, in terms of the channel and the permanent link. The channel is the transmission path between equipment such as a LAN switch/hub (EQP in Figure 7) and the terminal equipment. A typical channel would consist of the horizontal subsystem together with work area and equipment cords. For longer reach services the channel would be formed by the connection of two or more subsystems (including work area and equipment cords). The performance of the channel excludes the connections at the application-specific equipment.

The permanent link is the transmission path of an installed cabling subsystem including the connecting hardware at the ends of the installed cable. In the horizontal cabling subsystem, the permanent link consists of the telecommunications outlet, the horizontal cable, an optional CP and the termination of the horizontal cable at the floor distributor. The permanent link includes the connections at the ends of the installed cabling.

5.6.3 External network interface

Connections to the public network for the provision of public telecommunications services are made at the external network interface.

5.7 Dimensioning and configuring

5.7.1 Distributors

The number and type of subsystems that are included in a generic cabling implementation depends upon the geography and size of the campus or building, and upon the strategy of the user. Usually there would be one campus distributor per campus, one building distributor per building, and one floor distributor per floor. If the premise comprises only a single building which is small enough to be served by a single building distributor, there is no need for a campus backbone cabling subsystem. Similarly larger buildings may be served by multiple building distributors interconnected via a campus distributor.

The design of the floor distributor should ensure that the lengths of patch cords/jumpers and equipment cords are minimised and administration should ensure that the design lengths are maintained during operation.

Distributors shall be located in such a way that the resulting cable lengths are consistent with the channel performance requirements of Clauses 6 and 8.

In the case of the reference implementations described in Clause 7, distributors shall be located to ensure that the channel lengths in Table 1 are not exceeded. However, not all applications are supported over the maximum lengths shown in Table 1 using a single cable type. Table 33, Table 34 and Table 35 indicate that the support of specific applications over installed channels may require a mix of cabling media and performance specifications.

Table 1 – Maximum channel lengths

Channel	Length m
Horizontal	100
Horizontal + building backbone + campus backbone	2 000
NOTE In some implementations of the horizontal cabling subsystem in Clause 7, the FD may not support TOs up to the maximum distance shown.	

A minimum of one floor distributor should be provided for every floor; for floor spaces exceeding 1 000 m², a minimum of one floor distributor should be provided for every 1 000 m^2 of floor space reserved for offices. If a floor space is sparsely populated (for example a lobby), it is permissible to serve this floor from the floor distributor located on an adjacent floor. The functions of multiple distributors may be combined. Figure 8 shows an example of generic cabling. The building in the foreground shows an example with each distributor housed separately. The building in the background shows an example where the functions of a floor distributor and the building distributor have been combined into a single distributor.

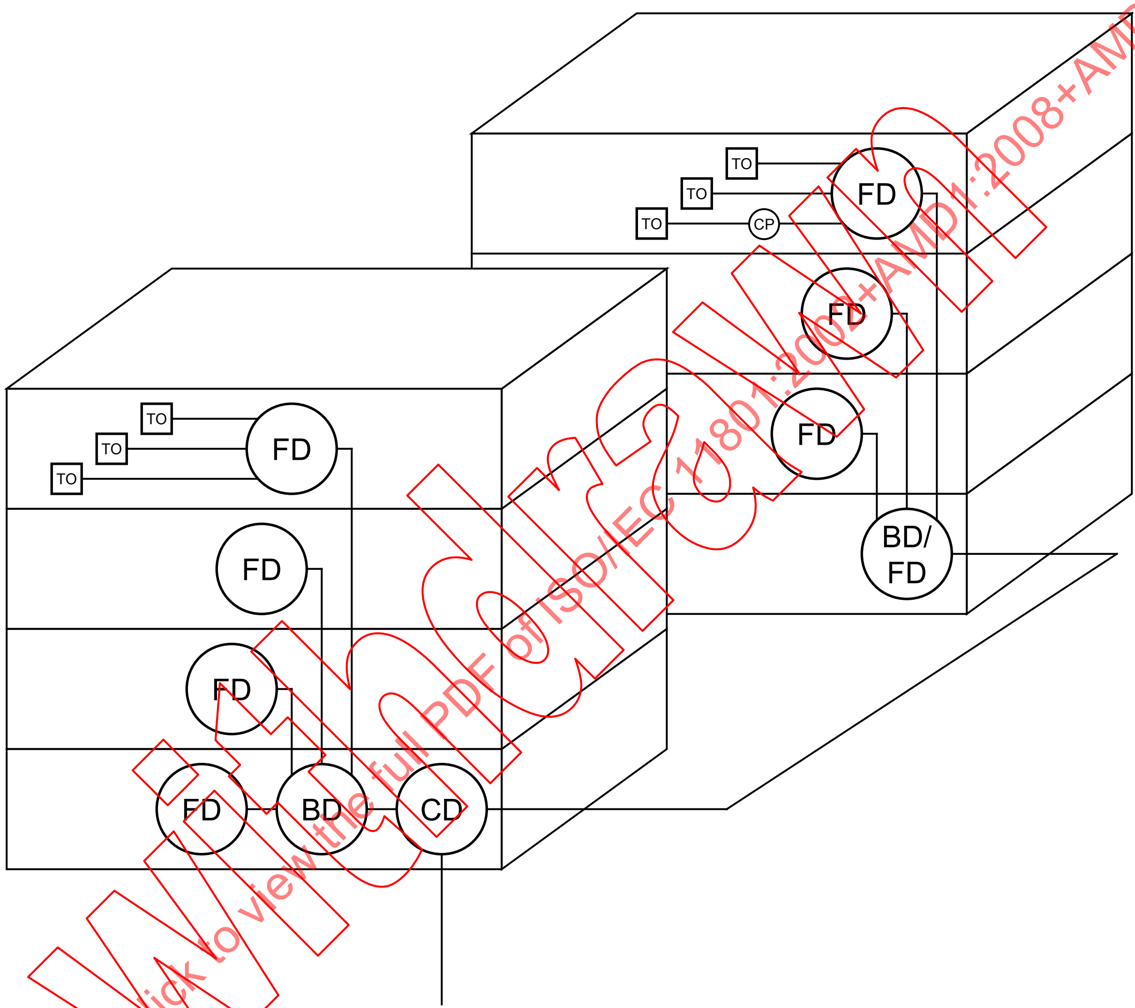


Figure 8 – Example of a generic cabling system with combined BD and FD

In certain circumstances, for example for reasons of security or reliability, redundancy may be built into a cabling design. Figure 9 gives one of many possible examples of the connection of functional elements within the structured framework in order to provide protection against failure within one or more parts of the cabling infrastructure. This might form the basis for the design of generic cabling for a building, providing some protection against such hazards as fire damage or the failure of the public network feeder cable.

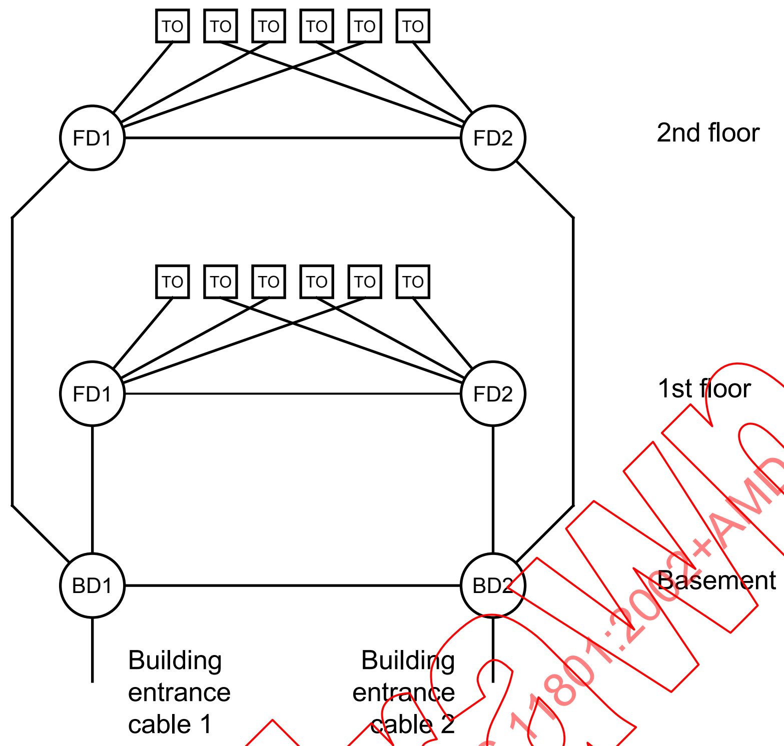


Figure 9 – Inter-relationship of functional elements in an installation with redundancy

5.7.2 Cables

For details of the use of the recommended cable types, see Clause 9. Hardware for connecting cables shall only provide direct onward attachment for each conductor and shall not provide contact between more than one incoming or outgoing conductor (for example, bridge taps shall not be used).

5.7.3 Work area cords and equipment cords

The work area cord connects the telecommunications outlet to the terminal equipment. Equipment cords connect equipment to the generic cabling at distributors. Both are non-permanent and can be application-specific. Assumptions have been made concerning the length and the transmission performance of these cords; the assumptions are identified when relevant. The performance contribution of these cords shall be taken into account in the design of the channel. Clause 7 provides guidance on cord length for reference implementations of generic cabling.

5.7.4 Patch cords and jumpers

Patch cords and jumpers are used within cross-connect implementations at distributors. The performance contribution of these cords shall be taken into account in the design of the channel. Clause 7 provides guidance on cord/jumper lengths for reference implementations of generic cabling.

5.7.5 Telecommunications outlet (TO)

5.7.5.1 General requirements

The design of generic cabling should insure that telecommunications outlets are installed throughout the usable floor space. A high density of telecommunications outlets will enhance the ability of the cabling to accommodate changes. Telecommunications outlets may be presented individually or in groups.

- Each individual work area shall be served by a minimum of two TOs. Requirements on work area size are given in ISO/IEC 14763-2 (first edition). Until ISO/IEC 14763-2 is published, relevant information can be found in ISO/IEC TR 14763-2.
- The first outlet should be for 4 pair balanced cable terminated in accordance with 10.2.1.
- The second outlet may be for:
  - a) optical fibre or
  - b) 4 pair balanced cable terminated in accordance with 10.2.1;
- Each telecommunications outlet shall have a permanent means of identification that is visible to the user.
- Devices such as baluns and impedance matching adapters, if used, shall be external to the outlet.

For balanced cables, 2 pairs per TO may be used as an alternative to 4 pairs. However, this may require pair reassignment and will not support some applications (see Annex F). Care should be taken that the initial pair assignment, and all subsequent changes, are recorded (see ISO/IEC 14763-2 for details of administration requirements. Until ISO/IEC 14763-2 (first edition) is published, relevant information can be found in ISO/IEC TR 14763-2). Pair reassignment by means of inserts is allowed.

5.7.5.2 Single user TO assembly

In a general implementation of generic cabling, one assembly of TOs serves a single work area. The length of work area cords should be minimised. The implementation topology shall be selected from the options described in 7.2.2.2 (for balanced cabling) and in 8.4 (for optical fibre cabling). The assembly of TOs shall be known as a single user TO assembly.

In addition, where the single user TO assembly is used:

a) a single user TO assembly should be located in user-accessible locations;

b) the performance contribution of work area cords, patch cords and equipment cords shall be taken into account to ensure that the channel requirements of Clause 6 (for balanced cabling) and Clause 8 (for optical fibre cabling) are met.

5.7.5.3 Multi-user TO assembly (MUTO)

In an open office environment, a single assembly of TOs may be used to serve more than one work area. The implementation topology shall be selected from the options described in 7.2.2.2 (for balanced cabling) and in 8.4 (for optical fibre cabling), and the assembly of TOs shall be known as a multi-user TO assembly.

In addition, where the multi-user TO assembly is used:

a) a multi-user TO assembly shall be located in an open work area so that each work area group is served by at least one multi-user TO assembly;

b) a multi-user TO assembly should be limited to serving a maximum of twelve work areas;

c) a multi-user TO assembly should be located in user-accessible, permanent locations such as on building columns and permanent walls;

d) a multi-user TO assembly shall not be installed in obstructed areas:

e) the performance contribution of work area cords, patch cords and equipment cords shall be taken into account to ensure that the channel requirements of Clause 6 (for balanced cabling) and Clause 8 (for optical fibre cabling) are met;

f) the length of the work area cord should be limited to ensure cable management in the work area.

5.7.6 Consolidation point

The installation of a consolidation point in the horizontal cabling between the floor distributor and the telecommunications outlet may be useful in an open office environment where the flexibility of relocating TOs in the work area is required. One consolidation point is permitted between a FD and any TO. The consolidation point shall only contain passive connecting hardware and shall not be used for cross-connections.

In addition, where a consolidation point is used:

a) the consolidation point shall be located so that each work area group is served by at least one consolidation point;

b) the consolidation point should be limited to serving a maximum of twelve work areas;

c) a consolidation point should be located in accessible locations;

d) a consolidation point shall be part of the administration system.

5.7.7 Telecommunications rooms and equipment rooms

A telecommunications room should provide all the facilities (space, power, environmental control etc.) for passive components, active devices, and external network interfaces housed within it. Each telecommunications room should have direct access to the backbone cabling subsystem.

An equipment room is an area within a building where equipment is housed. Equipment rooms are treated differently from telecommunications rooms because of the nature or complexity of the equipment (for example, PBXs or extensive computer installations). More than one distributor may be located in an equipment room. If a telecommunications room serves more than one building distributor it should be considered an equipment room.

5.7.8 Building entrance facilities

Building entrance facilities are required whenever campus backbone, public and private network cables (including from antennae) enter buildings and a transition is made to internal cables. It comprises an entrance point from the exterior of the building and the pathway leading to the campus or building distributor. Local regulations may require special facilities where the external cables are terminated. At this termination point, a change from external to internal cable can take place.

5.7.9 External services cabling

The distance from external services to a distributor can be significant. The performance of the cable between these points should be considered as part of the initial design and implementation of customer applications.

6 Performance of balanced cabling

6.1 General

This clause specifies the minimum performance of generic balanced cabling. The performance of balanced cabling is specified for channels, permanent links and CP links (see Figure 10).

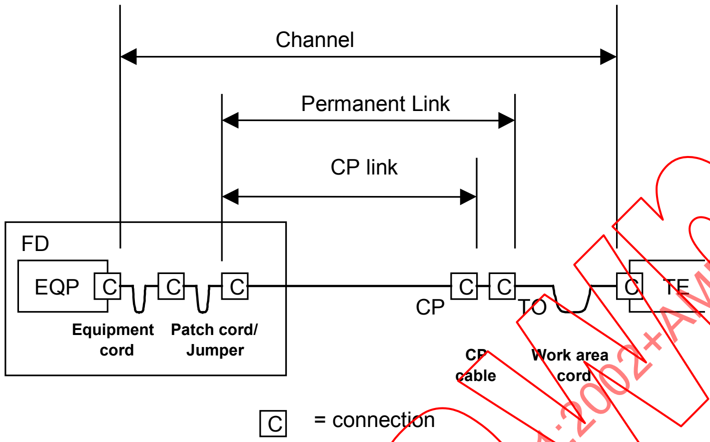


Figure 10 – Balanced cabling: channel, permanent link and CP link

In the case of cable sharing, additional requirements should be taken into account for balanced cabling. The additional crosstalk requirements for balanced cables are specified in 9.3.

The performance specifications are separated into six classes (A to F) for balanced cabling. This allows the successful transmission of applications over channels according to Annex F which lists the applications and the minimum class required.

The channel performance requirements described in this clause may be used for the design and verification of any implementation of this International Standard. Where required, the test methods defined or referred to by this clause, shall apply. In addition, these requirements can be used for application development and troubleshooting.

The permanent link and CP link performance requirements described in Annex A may be used for acceptance testing of any implementation of this International Standard. Where required, the test methods defined or referred to by Annex A, shall apply.

The specifications in this clause allow for the transmission of defined classes of applications over distances other than those of 7.2, and/or using media and components with different performances than those specified in Clauses 9, 10 and 13.

The channel, permanent link and CP link performance specification of the relevant class shall be met for all temperatures at which the cabling is intended to operate.

There shall be adequate margins to account for temperature dependence of cabling components as per relevant standards and suppliers' instructions. In particular, consideration should be given to measuring performance at worst case temperatures, or calculating worst case performance based on measurements made at other temperatures.

Compatibility between cables used in the same channel or permanent link shall be maintained throughout the cabling system. For example, connections between cables with different nominal impedance shall not be made.

6.2 Layout

The performance of a channel is specified at and between connections to active equipment. The channel comprises only passive sections of cable, connecting hardware, work area cords, equipment cords and patch cords. The connections at the hardware interface to active equipment are not taken into account.

Application support depends on channel performance only, which in turn depends on cable length, number of connections, connector termination practices and workmanship, and performance. It is possible to achieve equivalent channel performance over greater lengths by the use of fewer connections or by using components with higher performance (see also Annex G).

The performance limits for balanced cabling channels are given in 6.4. These limits are derived from the component performance limits of Clause 9 and 10 using reference implementations specified in Clause 7.

Figure 11 shows an example of terminal equipment in the work area connected to transmission equipment using two different media channels which are cascaded. In fact, there is an optical fibre cabling channel (see Clause 8) connected via an active component in the FD to a balanced cabling channel. There are four channel interfaces; one at each end of the balanced channel and one at each end of the optical fibre cabling channel.

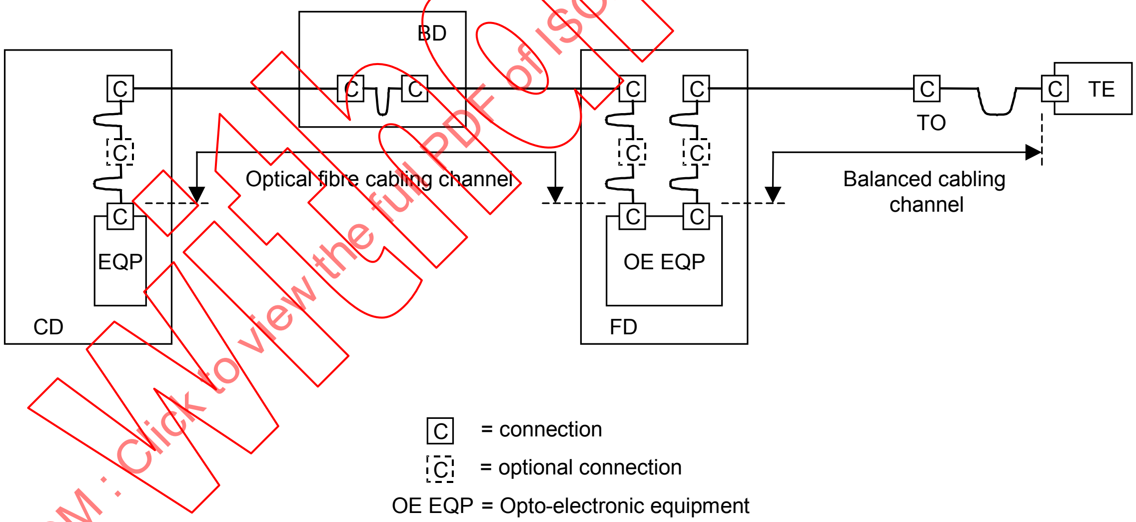


Figure 11 – Example of a system showing the location of cabling interfaces and extent of associated channels

The performance of a permanent link is specified for horizontal cabling at and between the TO and the first patch panel at the other side of the horizontal cable; it may contain a CP. The performance of a CP link is specified for horizontal cabling at and between the CP and the first patch panel at the other side of the horizontal cable. For backbone cabling the permanent link is specified at and between the patch panels at each side of the backbone cable. The permanent link and CP link comprise only passive sections of cable and connecting hardware.

The performance limits for balanced cabling permanent links and CP links are given in Annex A. These limits are derived from the component performance limits of Clauses 9 and 10 using reference implementations specified in Clause 7.

6.3 Classification of balanced cabling

This standard specifies the following classes for balanced cabling.

Class A is specified up to 100 kHz.

Class B is specified up to 1 MHz.

Class C is specified up to 16 MHz.

Class D is specified up to 100 MHz.

Class E is specified up to 250 MHz.

Class E_A is specified up to 500 MHz.

Class F is specified up to 600 MHz.

Class F_A is specified up to 1 000 MHz.

A Class A channel is specified so that it will provide the minimum transmission performance to support Class A applications. Similarly, Class B, C, D, E, E_A, F and F_A channels provide the transmission performance to support Class B, C, D, E, E_A, F and F_A applications respectively. Links and channels of a given class will support all applications of a lower class. Class A is regarded as the lowest class.

Channels, permanent links and CP links in the horizontal cabling shall be installed to provide a minimum of Class D performance.

Annex F lists known applications by classes.

6.4 Balanced cabling performance

6.4.1 General

The parameters specified in this subclause apply to channels with screened or unscreened cable elements, with or without an overall screen, unless explicitly stated otherwise.

The nominal impedance of channels is 100 Ω. This is achieved by suitable design and appropriate choice of cabling components (irrespective of their nominal impedance). For the purposes of this standard, insertion loss is measured with source and load impedances of 100 Ω.

The requirements in this subclause are given by limits computed to one decimal place, using the equation for a defined frequency range. The limits for the propagation delay and delay skew are computed to three decimal places. The additional tables are for information only and have limits derived from the relevant equation at key frequencies. When required for assessment, channels shall be measured according to IEC 61935-1, unless otherwise specified in this clause.

6.4.2 Return loss

The return loss requirements are applicable to Classes C, D, E. E_A, F and F_A only.

The return loss (*RL*) of each pair of a channel shall meet the requirements derived by the equation in Table 2.

The return loss requirements shall be met at both ends of the cabling. Return loss (*RL*) values at frequencies where the insertion loss (*IL*) is below 3,0 dB are for information only.

When required, the return loss (*RL*) shall be measured according to IEC 61935-1. Terminations of 100 Ω shall be connected to the cabling elements under test at the remote end of the channel.

Table 2 – Return loss for channel

Class	Frequency MHz	Minimum return loss dB
C	$1 \le f \le 16$	15,0
D	$1 \le f < 20$	17,0
	$20 \le f \le 100$	$30 - 10 \lg(f)$
E	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5 \lg(f)$
	$40 \le f \le 250$	$32 - 10 \lg(f)$
E_A	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5 \lg(f)$
	$40 \le f < 398.1$	$32 - 10 \lg(f)$
	$398.1 \le f \le 500$	6,0
F	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5 \lg(f)$
	$40 \le f < 251,2$	$32 - 10 \lg(f)$
	$251,2 \le f \le 600$	8,0
F_A	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5 \lg(f)$
	$40 \le f < 251,2$	$32 - 10 \lg(f)$
	$251,2 \le f < 631$	8,0
	$631 \le f \le 1\,000$	$36 - 10 \lg(f)$

Table 3 – Informative return loss values for channel at key frequencies

Frequency MHz	Minimum return loss dB					
	Class C	Class D	Class E	Class E_A	Class F	Class F_A
1	15,0	17,0	19,0	19,0	19,0	19,0
16	15,0	17,0	18,0	18,0	18,0	18,0
100	N/A	10,0	12,0	12,0	12,0	12,0
250	N/A	N/A	8,0	8,0	8,0	8,0
500	N/A	N/A	N/A	6,0	8,0	8,0
600	N/A	N/A	N/A	N/A	8,0	8,0
1 000	N/A	N/A	N/A	N/A	N/A	6,0

6.4.3 Insertion loss/attenuation

Previous editions of this standard use the term “attenuation”, which is still widely used in the cable industry. However, due to impedance mismatches in cabling systems, especially at higher frequencies, this characteristic is better described as “insertion loss”. In this edition, the term “insertion loss” is adopted throughout to describe the signal attenuation over the length of channels, links and components. Unlike attenuation, insertion loss does not scale linearly with length.

The term “attenuation” is maintained for the following parameters:

- attenuation to crosstalk ratio at the near-end (*ACR-N*) – see 6.4.5;
- attenuation to crosstalk ratio at the far-end (*ACR-F*) – see 6.4.6;
- unbalance attenuation – see 6.4.14;
- coupling attenuation – see 6.4.14.

For the calculation of *ACR-N*, *PS ACR-N*, *ACR-F* and *PS ACR-F*, the corresponding value for insertion loss (*IL*) shall be used.

The insertion loss (*IL*) of each pair of a channel shall meet the requirements derived by the equation in Table 4.

When required, the insertion loss shall be measured according to IEC 61935-1.

Table 4 – Insertion loss for channel

Class	Frequency MHz	Maximum insertion loss [a] dB
A	$f = 0{,}1$	16,0
B	$f = 0{,}1$	5,5
	$f = 1$	5,8
C	$1 \le f \le 16$	$1{,}05 \times \left(3{,}23\sqrt{f}\right) + 4 \times 0{,}2$
D	$1 \le f \le 100$	$1{,}05 \times \left(1{,}910\,8\sqrt{f} + 0{,}022\,2 \times f + 0{,}2/\sqrt{f}\right) + 4 \times 0{,}04 \times \sqrt{f}$
E	$1 \le f \le 250$	$1{,}05 \times \left(1{,}82\sqrt{f} + 0{,}016\,9 \times f + 0{,}25/\sqrt{f}\right) + 4 \times 0{,}02 \times \sqrt{f}$
E_A	$1 \le f \le 500$	$1{,}05 \times \left(1{,}82\sqrt{f} + 0{,}009\,1 \times f + 0{,}25/\sqrt{f}\right) + 4 \times 0{,}02 \times \sqrt{f}$
F	$1 \le f \le 600$	$1{,}05 \times \left(1{,}8\sqrt{f} + 0{,}01 \times f + 0{,}2/\sqrt{f}\right) + 4 \times 0{,}02 \times \sqrt{f}$
F_A	$1 \le f \le 1\,000$	$1{,}05 \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + 0{,}25/\sqrt{f}\right) + 4 \times 0{,}02 \times \sqrt{f}$

[a] Insertion loss (*IL*) at frequencies that correspond to calculated values of less than 4,0 dB shall revert to a maximum requirement of 4,0 dB.

Table 5 – Informative insertion loss values for channel at key frequencies

Frequency MHz	Maximum insertion loss dB							
	Class A	Class B	Class C	Class D	Class E	Class E_A	Class F	Class F_A
0,1	16,0	5,5	N/A	N/A	N/A	N/A	N/A	N/A
1	N/A	5,8	4,2	4,0	4,0	4,0	4,0	4,0
16	N/A	N/A	14,4	9,1	8,3	8,2	8,1	8,0
100	N/A	N/A	N/A	24,0	21,7	20,9	20,8	20,3
250	N/A	N/A	N/A	N/A	35,9	33,9	33,8	32,5
500	N/A	N/A	N/A	N/A	N/A	49,3	49,3	46,7
600	N/A	N/A	N/A	N/A	N/A	N/A	54,6	51,4
1 000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	67,6

6.4.4 NEXT

6.4.4.1 Pair-to-pair NEXT

The *NEXT* between each pair combination of a channel shall meet the requirements derived by the equation in Table 6.

The *NEXT* requirements shall be met at both ends of the cabling. *NEXT* values at frequencies where the insertion loss (*IL*) is below 4,0 dB are for information only.

When required, the *NEXT* shall be measured according to IEC 61935-1.

Table 6 – NEXT for channel

Class	**Frequency** MHz	**Minimum NEXT** [a] dB
A	$f = 0,1$	27,0
B	$0,1 \le f \le 1$	$25 - 15\lg(f)$
C	$1 \le f \le 16$	$39,1 - 16,4\lg(f)$
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{65,3-15\lg(f)}{-20}} + 2\times 10^{\frac{83-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{74,3-15\lg(f)}{-20}} + 2\times 10^{\frac{94-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{74,3-15\lg(f)}{-20}} + 2\times 10^{\frac{94-20\lg(f)}{-20}}\right)$ [b, d]
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{102,4-15\lg(f)}{-20}} + 2\times 10^{\frac{102,4-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{105,4-15\lg(f)}{-20}} + 2\times 10^{\frac{116,3-20\lg(f)}{-20}}\right)$ [c, d]

[a] *NEXT* at frequencies that correspond to calculated values of greater than 65,0 dB shall revert to a minimum requirement of 65,0 dB.

[b] Whenever the Class E_A channel insertion loss at 450 MHz is less than 12 dB, subtract the term $1,4((f-450)/50)$ to the equation stated above for the range of 450 MHz to 500 MHz.

[c] Whenever the Class F_A channel insertion loss at 900 MHz is less than 17 dB, subtract the term $2,8((f-900)/100)$ to the equation stated above for the range of 900 MHz to 1 000 MHz.

[d] The terms in the equations are not intended to imply component performance.

Table 7 – Informative NEXT values for channel at key frequencies

Frequency MHz	Minimum channel NEXT dB							
	Class A	Class B	Class C	Class D	Class E	Class E_A	Class F	Class F_A
0,1	27,0	40,0	N/A	N/A	N/A	N/A	N/A	N/A
1	N/A	25,0	39,1	63,3	65,0	65,0	65,0	65,0
16	N/A	N/A	19,4	43,6	53,2	53,2	65,0	65,0
100	N/A	N/A	N/A	30,1	39,9	39,9	62,9	65,0
250	N/A	N/A	N/A	N/A	33,1	33,1	56,9	59,1
500	N/A	N/A	N/A	N/A	N/A	27,9	52,4	53,6
600	N/A	N/A	N/A	N/A	N/A	N/A	51,2	52,1
1 000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	47,9

6.4.4.2 Power sum NEXT (PS NEXT)

The *PS NEXT* requirements are applicable only to Classes D, E, E_A, F and F_A only.

The *PS NEXT* of each pair of a channel shall meet the requirements derived by the equation in Table 8.

The PS NEXT requirements shall be met at both ends of the cabling. *PS NEXT* values at frequencies where the insertion loss (*IL*) is below 4,0 dB are for information only.

$PS\ NEXT_k$ of pair *k* is computed as follows:

$$PS\ NEXT_k = -10\lg \sum_{i=1, i \neq k}^{n} 10^{\frac{-NEXT_{ik}}{10}} \qquad (1)$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

n is the total number of pairs;

$NEXT_{ik}$ is the near end crosstalk loss coupled from pair *i* into pair *k*.

Table 8 – PS NEXT for channel

Class	Frequency MHz	Minimum PS NEXT [a] dB
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{62,3-15\lg(f)}{-20}} + 2\times 10^{\frac{80-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}} + 2\times 10^{\frac{90-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}} + 2\times 10^{\frac{90-20\lg(f)}{-20}}\right)$ [b, d]
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{99,4-15\lg(f)}{-20}} + 2\times 10^{\frac{99,4-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{102,4-15\lg(f)}{-20}} + 2\times 10^{\frac{113,3-20\lg(f)}{-20}}\right)$ [c, d]

[a] *PS NEXT* at frequencies that correspond to calculated values of greater than 62,0 dB shall revert to a minimum requirement of 62,0 dB.

[b] Whenever the Class E_A channel insertion loss at 450 MHz is less than 12 dB, subtract the term $1{,}4((f - 450)/50)$ from the equation stated above for the range of 450 MHz to 500 MHz.

[c] Whenever the Class F_A channel insertion loss at 900 MHz is less than 17 dB, subtract the term $2{,}8((f - 900)/100)$ from the equation stated above for the range of 900 MHz to 1 000 MHz.

[d] The terms in the equations are not intended to imply component performance.

Table 9 – Informative PS NEXT values for channel at key frequencies

Frequency MHz	Minimum PS NEXT dB				
	Class D	Class E	Class E_A	Class F	Class F_A
1	60,3	62,0	62,0	62,0	62,0
16	40,6	50,6	50,6	62,0	62,0
100	27,1	37,1	37,1	59,9	62,0
250	N/A	30,2	30,2	53,9	56,1
500	N/A	N/A	24,8	49,4	50,6
600	N/A	N/A	N/A	48,2	49,1
1 000	N/A	N/A	N/A	N/A	44,9

6.4.5 Attenuation to crosstalk ratio at the near-end (ACR-N)

6.4.5.1 General

ACR-N and *PS ACR-N* requirements are applicable to Classes D, E, E_A, F and F_A only.

Except for the name, the definition and equations for *ACR-N* and *PS ACR-N* are identical to those used for *ACR* and *PS ACR,* respectively, in prior editions of this standard.

6.4.5.2 Pair-to-pair ACR-N

Pair-to-pair *ACR-N* is the difference between the pair-to-pair *NEXT* and the insertion loss (*IL*) of the disturbed pair in dB.

The *ACR-N* of each pair combination of a channel shall meet the difference of the *NEXT* requirement of Table 6 and the insertion loss (*IL*) requirement of Table 4 of the respective class.

The *ACR-N* requirements shall be met at both ends of the cabling.

$ACR\text{-}N_{ik}$ of pairs *i* and *k* is computed as follows:

$$ACR\text{-}N_{ik} = NEXT_{ik} - IL_k \qquad (2)$$

where

- i is the number of the disturbing pair;
- k is the number of the disturbed pair;
- $NEXT_{ik}$ is the near-end crosstalk loss coupled from pair *i* into pair *k*;
- IL_k is the insertion loss of pair *k*.

Table 10 – Informative ACR-N values for channel at key frequencies

Frequency MHz	Minimum ACR-N dB				
	Class D	**Class E**	**Class E_A**	**Class F**	**Class F_A**
1	59,3	61,0	61,0	61,0	61,0
16	34,5	44,9	45,0	56,9	57,0
100	6,1	18,2	19,0	42,1	44,7
250	N/A	−2,8	−0,8	23,1	26,7
500	N/A	N/A	−21,4	3,1	6,9
600	N/A	N/A	N/A	-3,4	0,7
1 000	N/A	N/A	N/A	N/A	−19,6

6.4.5.3 Power sum ACR-N (PS ACR-N)

The *PS ACR-N* of each pair of a channel shall meet the difference of the *PS NEXT* requirement of Table 8 and the insertion loss (*IL*) requirement of Table 4 of the respective class. The *PS ACR-N* requirements shall be met at both ends of the cabling.

PS ACR-N$_k$ of pair *k* is computed as follows:

$$PS\ ACR\text{-}N_k = PS\ NEXT_k - IL_k \tag{3}$$

where

k is the number of the disturbed pair;

PS NEXT$_k$ is the power sum near-end crosstalk loss of pair *k*;

IL$_k$ is the insertion loss of pair *k.*

Table 11 – Informative PS ACR-N values for channel at key frequencies

Frequency MHz	**Minimum PS ACR-N** dB				
	Class D	**Class E**	**Class E$_A$**	**Class F**	**Class F$_A$**
1	56,3	58,0	58,0	58,0	58,0
16	31,5	42,3	42,4	53,9	54,0
100	3,1	15,4	16,2	39,1	41,7
250	N/A	−5,8	−3,7	20,1	23,7
500	N/A	N/A	−24,5	0,1	3,9
600	N/A	N/A	N/A	−6,4	−2,3
1 000	N/A	N/A	N/A	N/A	−22,6

6.4.6 Attenuation to crosstalk ratio at the far-end (ACR-F)

6.4.6.1 General

ACR-F and *PS ACR-F* requirements are applicable to Classes D, E, E$_A$, F and F$_A$ only.

NOTE *ACR-F* and *PS ACR-F* replace parameters *ELFEXT* and *PS ELFEXT* respectively, which were specified in prior editions of this standard. Whereas *ELFEXT* is computed using the insertion loss of the disturbing pair, *ACR-F* is computed using the insertion loss of the disturbed pair. Because both disturbing pairs and disturbed pairs are subject to the same insertion loss requirements (see Table 4), the specified requirements in Table 12 and Table 14 for Classes D, E and F have not been changed.

6.4.6.2 Pair-to-pair ACR-F

The *ACR-F* of each pair combination of a channel shall meet the requirements derived by the equations in Table 12.

ACR-F$_{ik}$ of pairs *i* and *k* is computed as follows:

$$ACR\text{-}F_{ik} = FEXT_{ik} - IL_k \tag{4}$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

FEXT$_{ik}$ is the far-end crosstalk loss coupled from pair *i* into pair *k;*

IL$_k$ is the insertion loss of pair *k.*

Table 12 – ACR-F for channel

Class	Frequency MHz	Minimum ACR-F [a, b] dB
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{63{,}8-20\lg(f)}{-20}}+4\times 10^{\frac{75{,}1-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{67{,}8-20\lg(f)}{-20}}+4\times 10^{\frac{83{,}1-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{67{,}8-20\lg(f)}{-20}}+4\times 10^{\frac{83{,}1-20\lg(f)}{-20}}\right)$
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{94-20\lg(f)}{-20}}+4\times 10^{\frac{90-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{95{,}3-20\lg(f)}{-20}}+4\times 10^{\frac{103{,}9-20\lg(f)}{-20}}\right)$

[a] *ACR-F* at frequencies that correspond to measured FEXT values of greater than 70,0 dB are for information only.

[b] The *ACR-F* limit at frequencies that correspond to calculated values of greater than 65,0 dB shall revert to a minimum requirement of 65,0 dB.

Table 13 – Informative ACR-F values for channel at key frequencies

Frequency MHz	Minimum ACR-F dB				
	Class D	Class E	Class E_A	Class F	Class F_A
1	57,4	63,3	63,3	65,0	65,0
16	33,3	39,2	39,2	57,5	63,3
100	17,4	23,3	23,3	44,4	47,4
250	N/A	15,3	15,3	37,8	39,4
500	N/A	N/A	9,3	32,6	33,4
600	N/A	N/A	N/A	31,3	31,8
1 000	N/A	N/A	N/A	N/A	27,4

6.4.6.3 Power sum ACR-F (PS ACR-F)

The *PS ACR-F* of each pair of a channel shall meet the requirements derived by the equation in Table 14.

PS ACR-F$_k$ of pair k is computed as follows:

$$PS\,ACR\text{-}F_k = \left(-10\lg \sum_{i=1,\, i \neq k}^{n} 10^{\frac{-FEXT_{ik}}{10}} \right) - IL_k \qquad (5)$$

where

- i is the number of the disturbing pair;
- k is the number of the disturbed pair;
- n is the number of disturbing pairs in the channel;
- $FEXT_{ik}$ is the far-end crosstalk loss coupled from pair i into pair k;
- IL_k is the insertion loss of pair k.

Table 14 – PS ACR-F for channel

Class	**Frequency** MHz	**Minimum PS ACR-F** [a, b] dB
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{60{,}8-20\lg(f)}{-20}} + 4\times 10^{\frac{72{,}1-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{64{,}8-20\lg(f)}{-20}} + 4\times 10^{\frac{80{,}1-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{64{,}8-20\lg(f)}{-20}} + 4\times 10^{\frac{80{,}1-20\lg(f)}{-20}}\right)$
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{91-20\lg(f)}{-20}} + 4\times 10^{\frac{87-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{92{,}3-20\lg(f)}{-20}} + 4\times 10^{\frac{100{,}9-20\lg(f)}{-20}}\right)$

[a] *PS ACR-F* at frequencies that correspond to calculated *PS FEXT* values of greater than 67,0 dB are for information only.

[b] The *PS ACR-F* limit at frequencies that correspond to calculated values of greater than 62,0 dB shall revert to a minimum requirement of 62,0 dB.

Table 15 – Informative PS ACR-F values for channel at key frequencies

Frequency MHz	Minimum PS ACR-F dB				
	Class D	Class E	Class E_A	Class F	Class F_A
1	54,4	60,3	60,3	62,0	62,0
16	30,3	36,2	36,2	54,5	60,3
100	14,4	20,3	20,3	41,4	44,4
250	N/A	12,3	12,3	34,8	36,4
500	N/A	N/A	6,3	29,6	30,4
600	N/A	N/A	N/A	28,3	28,8
1 000	N/A	N/A	N/A	N/A	24,4

6.4.7 Direct current (d.c.) loop resistance

The d.c. loop resistance of each pair of a channel shall meet the requirements in Table 16.

When required, the d.c. loop resistance shall be measured according to IEC 61935-1.

Table 16 – Direct current (d.c.) loop resistance for channel

Maximum d.c. loop resistance Ω			
Class A	Class B	Class C	Class D, E, E_A, F, F_A
560	170	40	25

6.4.8 Direct current (d.c.) resistance unbalance

For all cabling classes, the d.c. resistance unbalance between the two conductors within each pair of a channel shall not exceed 3 % or 0,200 Ω, whichever is greater. This requirement shall be achieved by design. The maximum d.c. resistance unbalance between pairs within a channel is f.f.s.

6.4.9 Current carrying capacity

The minimum current carrying capacity for channels of Classes D, E, E_A, F and F_A shall be in accordance with Table 17. This shall be achieved by an appropriate design.

Table 17 – Current carrying capacity for channel

Minimum current carrying capacity A d.c.	Operating temperature (t) °C
0,300	$t \leq (T_R - 10)$
0,175	$(T_R - 10) < t \leq T_R$
Where T_R is the lowest maximum operating temperature specified for the components comprising the cabling subsystem.	

For information on current carrying capacity in respect to applications using remote power supplied over balanced cabling, see ISO/IEC TR 29125.

6.4.10 Dielectric withstand

Dielectric withstand of Classes D, E, E_A, F and F_A channels shall be a minimum of 1 000 V d.c. conductor-to-conductor and shall be a minimum of 1 000 V d.c. conductor-to-screen or conductor to earth, if a screen is not present. This requirement shall be met by design.

6.4.11 Power capacity

Void.

6.4.12 Propagation delay

The propagation delay of each pair of a channel shall meet the requirements derived by the equation in Table 18.

When required, the propagation delay shall be measured according to IEC 61935-1.

Table 18 – Propagation delay for channel

Class	Frequency MHz	Maximum propagation delay µs
A	$f = 0{,}1$	20,000
B	$0{,}1 \leq f \leq 1$	5,000
C, D, E, E_A, F, F_A	$1 \leq f \leq$ NOTE 1	$0{,}534 + 0{,}036/\sqrt{f} + 4 \times 0{,}002\,5$
NOTE The equation for propagation delay applies to the upper frequency of the class		

Table 19 – Informative propagation delay values for channel at key frequencies

Frequency MHz	Maximum propagation delay µs							
	Class A	Class B	Class C	Class D	Class E	Class E_A	Class F	Class F_A
0,1	20,000	5,000	N/A	N/A	N/A	N/A	N/A	N/A
1	N/A	5,000	0,580	0,580	0,580	0,580	0,580	0,580
16	N/A	N/A	0,553	0,553	0,553	0,553	0,553	0,553
100	N/A	N/A	N/A	0,548	0,548	0,548	0,548	0,548
250	N/A	N/A	N/A	N/A	0,546	0,546	0,546	0,546
500	N/A	N/A	N/A	N/A	N/A	0,546	0,546	0,546
600	N/A	N/A	N/A	N/A	N/A	N/A	0,545	0,545
1 000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0,545

6.4.13 Delay skew

The delay skew between all pairs of a channel shall meet the requirements in Table 20.

When required, the delay skew shall be calculated according to IEC 61935-1.

Table 20 – Delay skew for channel

Class	Frequency MHz	Maximum delay skew µs
A	f = 0,1	N/A
B	0,1 ≤ f ≤ 1	N/A
C	1 ≤ f ≤ 16	0,050 [a]
D	1 ≤ f ≤ 100	0,050 [a, c]
E	1 ≤ f ≤ 250	0,050 [a, c]
E_A	1 ≤ f ≤ 500	0,050 [a, c]
F	1 ≤ f ≤ 600	0,030 [b, c]
F_A	1 ≤ f ≤ 1 000	0,030 [b, c]

[a] This is the result of the calculation 0,045 + 4 × 0,001 25.

[b] This is the result of the calculation 0,025 + 4 × 0,001 25.

[c] Delay skew of any given installed cabling channel shall not vary by more than 0,010 µs within this requirement, due to effects such as the daily temperature variation.

6.4.14 Unbalance attenuation and coupling attenuation

6.4.14.1 General

This standard specifies unbalance attenuation (TCL and ELTCTL) for unscreened systems and coupling attenuation for screened systems. For further information on these parameters see Annex D.

6.4.14.2 Unbalance attenuation, near-end

The unbalance attenuation near-end is measured as transverse conversion loss (*TCL*). The TCL of a channel shall meet the requirements in Table 21. The TCL requirements shall be met at both ends of the cabling.

Performance requirements for TCL are applicable to Class A, B, C, D, E, E_A, F and F_A channels and shall be achieved by design and installation in accordance with manufacturer's instructions.

Table 21 – TCL for channel for unscreened systems

Class	Frequency MHz	Minimum TCL [a] dB
A	$f = 0,1$	30
B	$f = 0,1$	45
	$f = 1$	20
C	$1 \leq f \leq 16$	$30 - 5\lg(f)$
D, E, E_A, F, F_A	$1 \leq f < 30$	$53 - 15\lg(f)$
	$30 \leq f \leq$ NOTE [b]	$60,3 - 20\lg(f)$

NOTE This equation for TCL applies to upper frequency of the class.

[a] *TCL* at frequencies that correspond to calculated values of greater than 40,0 dB shall revert to a minimum requirement of 40,0 dB.

[b] TCL at frequencies above 250 MHz are for information only.

It is possible to assess TCL by laboratory measurements of representative samples of channels assembled using their component and connector termination practices.

6.4.14.3 Unbalance attenuation, far-end

The unbalance attenuation far-end is measured as equal level transverse conversion transfer loss (ELTCTL). The ELTCTL of a channel shall meet the requirements as indicated in Table 22. The ELTCTL requirements shall be met at both ends of the cabling.

Performance requirements for ELTCTL are applicable to Class D, E, E_A, F and F_A channels and shall be achieved by design and installation in accordance with manufacturer's instructions.

Table 22 – ELTCTL for channel for unscreened systems

Class	Frequency MHz	Minimum ELTCTL dB
D, E, E_A, F, F_A	$1 \leq f \leq 30$	$30 - 20\lg(f)$

It is possible to assess ELTCTL by laboratory measurements of representative samples of channels assembled using their component and connector termination practices.

6.4.14.4 Coupling attenuation

The coupling attenuation of a channel shall meet the requirements in Table 23 at both ends.

Performance requirements for coupling attenuation are applicable to Class D, E, E_A, F and F_A systems and shall be achieved by design and installation in accordance with manufacturer's instructions.

It is possible to assess coupling attenuation by laboratory measurements of representative samples of channels assembled using their component and connector termination practices.

Table 23 – Coupling attenuation for channel for screened systems

Class	**Frequency** MHz	**Minimum Coupling Attenuation** [a] dB
D, E, E_A, F, F_A	$30 \le f \le$ NOTE	$80 - 20\lg(f)$
NOTE Coupling attenuation is measured to 1 000 MHz but the limit applies to the upper frequency of the class under test.		
[a] Calculated values of greater than 40 dB shall revert to a minimum requirement of 40 dB.		

6.4.15 Alien crosstalk

6.4.15.1 General

The following alien crosstalk requirements are applicable only to Classes E_A and F_A. Alien crosstalk of Class F is considered to be as good as the alien crosstalk performance specified for Class E_A. For information on alien crosstalk performance of Class E systems, see ISO/IEC TR 24750.

If coupling attenuation for Class E_A or F channels is 10 dB better than Table 23 or for Class F_A channels is 25 dB better than Table 23, then *PS ANEXT* and *PS AACR-F* are met by design.

6.4.15.2 Power sum alien NEXT (PS ANEXT)

The *PS ANEXT* of each pair of a channel shall meet the requirements derived by the equation in Table 24.

The *PS ANEXT* requirements shall be met at both ends of the channel.

$PS\ ANEXT_k$ of pair *k* is computed as follows:

$$PS\ ANEXT_k = -10\lg\left[\sum_{l=1}^{N}\sum_{i=1}^{n} 10^{\frac{-ANEXT_{l,i,k}}{10}}\right] \qquad (6)$$

where

k is the number of the disturbed pair in the disturbed channel;

i is the number of the disturbing pair in a disturbing channel *l*;

l is the number of the disturbing channel;

N is the number of disturbing channels;

n is the number of disturbing pairs in disturbing channel l;

$ANEXT_{l,i,k}$ is the alien near-end crosstalk loss coupled from pair I of disturbing channel (l) to the pair *k* of the disturbed channel.

Table 24 – PS ANEXT for channel

Class	Frequency MHz	Minimum PS ANEXT [a] dB
E_A [b, c]	$1 \le f < 100$	$80 - 10\lg(f)$
	$100 \le f \le 500$	$90 - 15\lg(f)$
F_A	$1 \le f < 100$	$95 - 10\lg(f)$
	$100 \le f \le 1\,000$	$105 - 15\lg(f)$

[a] *PS ANEXT* at frequencies that correspond to calculated values of greater than 67,0 dB shall revert to a minimum requirement of 67,0 dB.

[b] If the average insertion loss of all disturbed pairs at 100 MHz, $IL_{100MHz,avg}$, is less than 7 dB, then subtract the following for $f \ge 100$ MHz:

$$\text{minimum}\left\{7\cdot\frac{f-100}{400}\cdot\frac{7-IL_{100MHz,avg}}{IL_{100MHz,avg}},\ 6\cdot\frac{f-100}{400}\right\}$$

where

f is the frequency in MHz;

$$IL_{100MHz,avg}=\frac{1}{4}\sum_{i=1}^{4}IL_{100MHz,i};$$

$IL_{100MHz,i}$ is the insertion loss of a pair I at 100 MHz.

[c] If coupling attenuation is at least 10 dB better than the requirements in Table 23, the calculation in [b] is not required.

Table 25 – Informative PS ANEXT values for channel at key frequencies

Frequency MHz	Minimum PS ANEXT dB	
	Class E_A	Class F_A
1	67,0	67,0
100	60,0	67,0
250	54,0	67,0
500	49,5	64,5
1 000	N/A	60,0

6.4.15.3 PS ANEXT$_{avg}$

The *PS ANEXT*$_{avg}$ of a channel shall meet the requirements derived by the equations in Table 26.

The *PS ANEXT*$_{avg}$ requirements shall be met at both ends of the channel.

PS ANEXT$_{avg}$ is computed as follows:

$$PS\ ANEXT_{avg} = \frac{1}{n}\left[\sum_{k=1}^{n} PS\ ANEXT_k\right] \quad (7)$$

where

- k is the number of the disturbed pair in the disturbed channel;
- n is the number of disturbed pairs in the disturbed channel;
- $PS\ ANEXT_k$ is the power sum alien near-end crosstalk loss coupled to pair k of the disturbed channel.

Table 26 – PS ANEXT$_{avg}$ for channel

Class	Frequency MHz	Minimum PS ANEXT$_{avg}$ [a, b, c, d] dB
E_A	$1 \le f < 100$	$82{,}25 - 10\lg(f)$
	$100 \le f \le 500$	$92{,}25 - 15\lg(f)$

[a] *PS ANEXT*$_{avg}$ at frequencies that correspond to calculated values of greater than 67,0 dB shall revert to a minimum requirement of 67,0 dB.

[b] If the average insertion loss of all disturbed pairs at 100 MHz, $IL_{100MHz,avg}$ is less than 7 dB, then subtract the following for $f \ge 100$ MHz:

$$\text{minimum}\left\{7 \cdot \frac{f-100}{400} \cdot \frac{7 - IL_{100MHz,\ avg}}{IL_{100MHz,\ avg}},\ 6 \cdot \frac{f-100}{400}\right\}$$

where

f is the frequency in MHz;

$$IL_{100MHz,avg} = \frac{1}{4}\sum_{i=1}^{4} IL_{100MHz,i};$$

$IL_{100MHz,i}$ is the insertion loss of a pair i at 100 MHz.

[c] If coupling attenuation is at least 10 dB better than the requirements in Table 23, the calculation in Footnote b is not required.

[d] *PS ANEXT*$_{avg}$ for Class F_A channels is met if the Class F_A PS ANEXT requirements in Table 24 are met.

Table 27 – Informative PS $ANEXT_{avg}$ values for channel at key frequencies

Frequency MHz	**Minimum Class E_A PS $ANEXT_{avg}$** dB
1	67,0
100	62,3
250	56,3
500	51,8

6.4.15.4 Power sum alien ACR-F (PS AACR-F)

The *PS AACR-F* of each pair of a channel shall meet the requirements in Table 28.

The *PS AACR-F* shall be met at both ends of the channel.

The *PS AACR-F* is computed based on *AFEXT*, and insertion losses of disturbing and disturbed channels.

6.4.15.5 PS AFEXT for Class E_A channels

The *PS AFEXT* for Class E_A is computed as follows:

If coupling attenuation is at least 10 dB better than the requirements in Table 23, then the *PS AFEXT* is determined by equation (13).

The measured pair-to-pair *AFEXT* values of a wire pair k in a disturbed channel from the disturbing channel l are normalized by the difference of the insertion losses of disturbing and disturbed channels.

$AFEXT_{norm}$ is computed from Equations 8 to 11 as follows

If

$$IL_k - IL_{l,i} > 0 \tag{8}$$

then

$$AFEXT_{\text{norm}\,l,i,k} = AFEXT_{l,i,k} - IL_{l,i} + IL_k - 10\lg\left(\frac{IL_k}{IL_{l,i}}\right) \tag{9}$$

If

$$IL_k - IL_{l,i} \le 0 \tag{10}$$

then

$$AFEXT_{\text{norm}\,l,i,k} = AFEXT_{l,i,k} \tag{11}$$

where

- k is the number of the disturbed pair in the disturbed channel;
- i is the number of the disturbing pair in a disturbing channel l;
- l is the number of the disturbing channel;
- $AFEXT_{l,l,k}$ is the alien far-end crosstalk loss coupled from pair l of disturbing channel (l) to the pair k of the disturbed channel;
- IL_k is the measured insertion loss of pair k in the disturbed channel;
- $IL_{l,l}$ is the measured insertion loss of pair l of disturbing channel l.

The *PS AFEXT* is determined according to Equation 12.

$$PS\,AFEXT_k = -10\lg\left(\sum_{l=1}^{N}\sum_{i=1}^{n} 10^{\frac{-\left(AFEXT_{\mathrm{norm}\,l,i,k}\right)}{10}}\right) \qquad (12)$$

where

- N is the number of disturbing channels;
- n is the number of disturbing pairs in disturbing channel l;
- k is the number of the disturbed pair in the disturbed channel;
- i is the number of the disturbing pair in a disturbing channel l;
- l is the number of the disturbing channel.

6.4.15.6 PS AFEXT for Class F_A channels

The *PS AFEXT* is determined according to Equation 13.

$$PS\,AFEXT_k = -10\lg\left(\sum_{l=1}^{N}\sum_{i=1}^{n} 10^{\frac{-\left(AFEXT_{l,i,k}\right)}{10}}\right) \qquad (13)$$

where

- N is the number of disturbing channels;
- n is the number of disturbing pairs in disturbing channel l;
- k is the number of the disturbed pair in the disturbed channel;
- i is the number of the disturbing pair in a disturbing channel l;
- l is the number of the disturbing channel;
- $AFEXT_{l,i,k}$ is the alien far-end crosstalk loss coupled from pair l of disturbing channel (l) to the pair k of the disturbed channel.

6.4.15.7 PS AACR-F for Class E_A and Class F_A channels

For Class E_A and F_A, the $PS\ AACR\text{-}F_k$ of disturbed pair k is determined according to Equation 14.

The *PS AACR-F* requirements shall be met at both ends of the channel.

$$PS\ AACR\text{-}F_k = PS\ AFEXT_k - IL_k \quad (14)$$

where

IL_k is the measured insertion loss of pair k in the disturbed channel;

$PS\ AFEXT_k$ is the power sum alien far-end crosstalk loss coupled to pair k.

Table 28 – PS AACR-F for channel

Class	Frequency MHz	Minimum PS AACR-F [a] dB
E_A	$1 \le f \le 500$	$77 - 20\lg(f)$
F_A	$1 \le f \le 1\,000$	$92 - 20\lg(f)$

[a] *PS AACR-F* at frequencies that correspond to calculated *PS AFEXT* values of greater than 67,0 dB or 102-15*lg(f) dB shall be for information only.

Table 29 – Informative PS AACR-F values for channel at key frequencies

Frequency MHz	Minimum PS AACR-F dB	
	Class E_A	Class F_A
1[a]	64,7	64,8
100	37,0	52,0
250	29,0	44,0
500	23,0	38,0
1 000	N/A	32,0

[a] *PS AACR-F* values at 1MHz are affected by the computed insertion loss.

6.4.15.8 PS AACR-F_{avg} for Class E_A and Class F_A channels

The $PS\ AACR\text{-}F_{avg}$ of a channel shall meet the requirements in Table 30.

The $PS\ AACR\text{-}F_{avg}$ requirements shall be met at both ends of the channel.

$PS\ AACR\text{-}F_{avg}$ is computed as follows:

$$PS\ AACR\text{-}F_{avg} = \frac{1}{n}\left[\sum_{k=1}^{n} PS\ AACR\text{-}F_k\right] \quad (15)$$

where

k is the number of the disturbed pair in the disturbed channel;

n is the number of disturbed pairs in the disturbed channel;

PS AACR-F$_k$ is the power sum alien far-end crosstalk loss coupled to pair *k* of the disturbed channel relative to insertion loss of pair *k* of the disturbed channel.

Table 30 – PS AACR-F$_{avg}$ for channel

Class	Frequency MHz	Minimum PS AACR-F$_{avg}$ [a, b] dB
E_A	$1 \le f \le 500$	$81 - 20\lg(f)$

[a] *PS AACR-F$_{avg}$* at frequencies that correspond to *PS AFEXT* values of greater than 67,0 dB or 102-15×lg(f) dB shall be for information only.

[b] The *PS AACR-F$_{avg}$* limit for Class F_A channels is equal to PS AACR-F specified in Table 28.

Table 31 – Informative PS AACR-F$_{avg}$ values for channel at key frequencies

Frequency MHz	Minimum Class E_A PS AACR-F$_{avg}$ dB
1[a]	64,7
100	41,0
250	33,0
500	27,0

[a] *PS AACR-F$_{avg}$* values at 1 MHz are affected by the computed insertion loss

7 Reference implementations for balanced cabling

7.1 General

This clause describes implementations of generic balanced cabling that utilise components and assemblies referenced in Clauses 9, 10 and 13. These reference implementations meet the requirements of Clause 5, and when installed in accordance with ISO/IEC 14763-2 (until ISO/IEC 14763-2 is published, relevant information can be found in ISO/IEC TR 14763-2), comply with the channel performance requirements of Clause 6.

7.2 Balanced cabling

7.2.1 General

Balanced components referenced in Clauses 9 and 10 are defined in terms of impedance and category. In the reference implementations of this clause, the components used in each cabling channel shall have the same nominal impedance in accordance with 9.2. The implementations are based on component performance at 20 °C. The effect of temperature on the performance of cables shall be accommodated by derating length as shown in Table 33 and Table 34.

Cables and connecting hardware of different categories may be mixed within a channel. However, the resultant cabling performance will be determined by the category of the lowest performing component.

7.2.2 Horizontal cabling

7.2.2.1 Component choice

The selection of balanced cabling components will be determined by the class of applications to be supported. Refer to Annex F for guidance.

The balanced cabling reference implementations described in this clause contain reductions in channel length where operating temperatures are in excess of 20 °C. In order to maintain specific channel lengths under such conditions (due to the effect of ambient temperature and/or the impact of applications supported by the cabling) it may be necessary to either:

- specify cables with lower insertion loss specifications than those detailed in this clause;
- provide appropriate protection to reduce the operating temperature of the channel.

Using the configurations of 7.2.2.2:

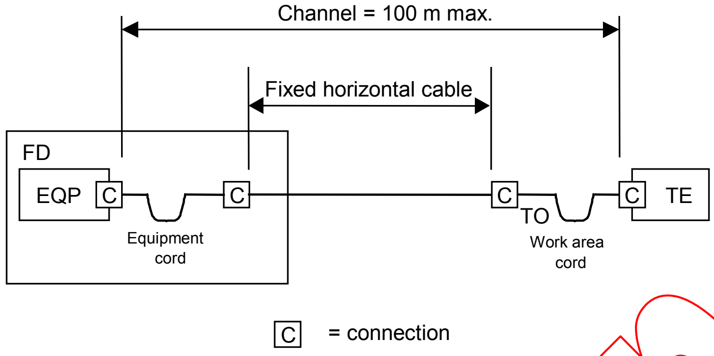
- Category 5 components provide Class D balanced cabling performance;
- Category 6 components provide Class E balanced cabling performance;
- Category 6_A components provide Class E_A balanced cabling performance;
- Category 7 components provide Class F balanced cabling performance;
- Category 7_A components provide Class F_A balanced cabling performance.

NOTE For the relationship and requirements of classes and categories in earlier editions of this standard, see Annex H.

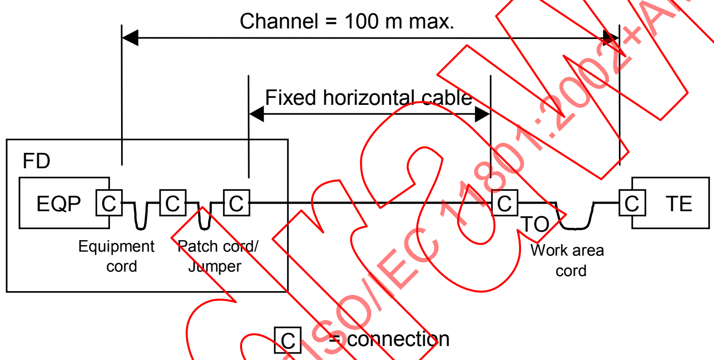
7.2.2.2 Dimensions

Figure 12 shows the models used to correlate horizontal cabling dimensions specified in this clause with the channel specifications in Clause 6.

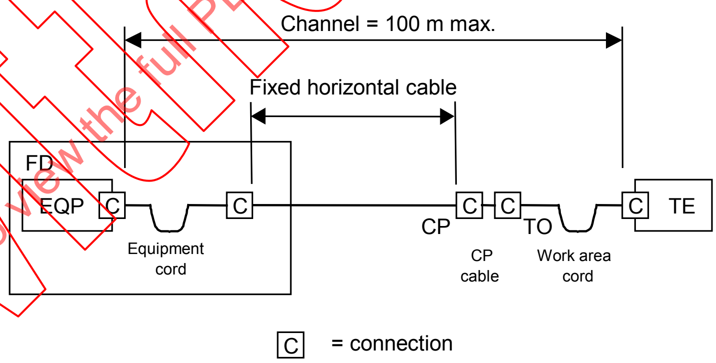
a) Interconnect - TO Model



b) Crossconnect - TO Model



c) Interconnect - CP - TO Model



d) Crossconnect - CP - TO Model

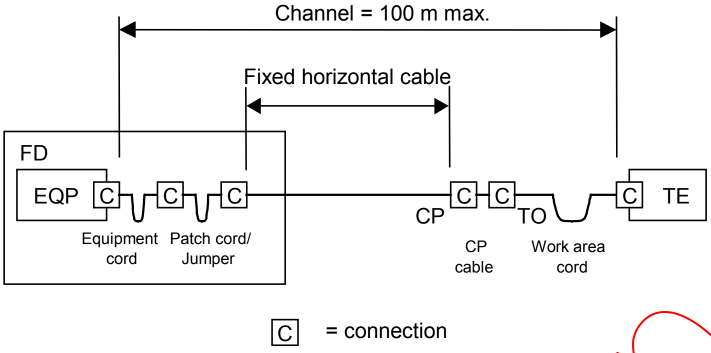


Figure 12 – Horizontal cabling models

Figure 12a shows a channel containing only an interconnect and a TO. Figure 12b contains an additional connection as a cross-connect. In both cases the fixed horizontal cable connects the FD to the TO or MUTO. The channel includes cords comprising patch cords/jumpers, equipment and work area cords.

Figure 12c shows a channel containing an interconnect, a CP and a telecommunications outlet. Figure 12d contains an additional connection as a cross-connect. In both cases the fixed horizontal cable connects the FD to the CP. The channel includes cords comprising patch cords/jumpers, equipment and work area cords.

Table 32 contains the length assumptions of the mathematical model used to validate channel performance using components of Clauses 9, 10 and 13. They do not represent absolute restrictions on the implementation of channels and permanent links, but may be used for guidance in reference implementations.

Table 32 – Length assumptions used in the mathematical modelling of balanced horizontal cabling

Segment	Minimum m	Maximum m
FD-CP	15	85
CP-TO	5	-
FD-TO (no CP)	15	90
Work area cord [a]	2	5
Patch cord	2	-
Equipment cord [b]	2	5
All cords	-	10

[a] If there is no CP, the minimum length of the work area cord is 1 m.

[b] If there is no cross-connect, the minimum length of the equipment cord is 1 m.

In addition to the cords, the channels shown in Figure 12c and Figure 12d contain a CP cable. The insertion loss specification for the CP cable may differ from that of both the fixed horizontal cable and the cords. In order to accommodate cables used for work area cords, CP cables, patch cords, jumpers and equipment cords with different insertion loss, the length of the cables used within a channel shall be determined by the equations shown in Table 33.

Table 33 – Horizontal channel length equations

Model	Figure	Implementation equation		
		Class D	Class E and E_A	Class F and F_A
Interconnect - TO	12a	$H = 109 – FX$	$H = 107 – 3$ [a] $– FX$	$H = 107 – 2$ [a] $– FX$
Cross-connect - TO	12b	$H = 107 – FX$	$H = 106 – 3$ [a] $– FX$	$H = 106 – 3$ [a] $– FX$
Interconnect - CP -TO	12c	$H = 107 – FX – CY$	$H = 106 - 3$ [a] $– FX – CY$	$H = 106 – 3$ [a] $– FX – CY$
Cross-connect - CP - TO	12d	$H = 105 – FX – CY$	$H = 105 - 3$ [a] $– FX – CY$	$H = 105 – 3$ [a] $– FX – CY$

H the maximum length of the fixed horizontal cable (m)

F combined length of patch cords/jumpers, equipment and work area cords (m)

C the length of the CP cable (m)

X the ratio of cord cable insertion loss (dB/m) to fixed horizontal cable insertion loss (dB/m)

Y the ratio of CP cable insertion loss (dB/m) to fixed horizontal cable insertion loss (dB/m)

NOTE For operating temperatures above 20 °C, H should be reduced by 0,2 % per °C for screened cables; 0,4 % per °C (20 °C to 40 °C) and 0,6 % per °C (>40 °C to 60 °C) for unscreened cables.

[a] This length reduction is to provide an allocated margin to accommodate insertion loss deviation.

For the purpose of calculation in Table 33 it is assumed that:

- the flexible cable within these cords has a higher insertion loss than that used in the fixed horizontal cable (see Clause 9);
- all the cords in the channel have a common insertion loss specification.

The following general restrictions apply:

- the physical length of the channel shall not exceed 100 m;
- the physical length of the fixed horizontal cable shall not exceed 90 m. When the total length of patch, equipment and work area cords exceeds 10 m, the allowed physical length of the fixed horizontal cable shall be reduced according to Table 33;
- a consolidation point shall be located so that there is at least 15 m from it to the floor distributor;
- where a multi-user TO assembly is used, the length of the work area cord should not exceed 20 m;
- the length of patch cords/jumper cables should not exceed 5 m.

The maximum length of the fixed horizontal cable will depend on the total length of cords to be supported within a channel. During the operation of the installed cabling, a management system should be implemented to ensure that the cords, jumper cables and, where appropriate, the CP cables used to create the channel conform to the design rules for the floor, building or installation.

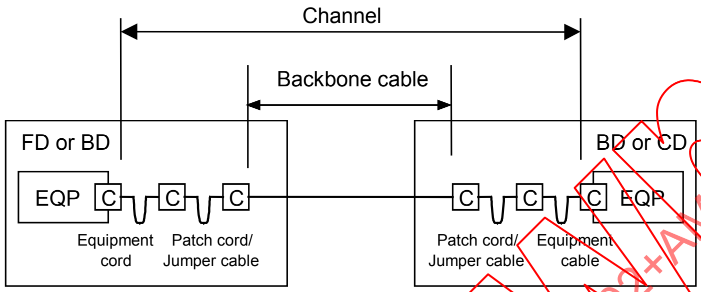
7.2.3 Backbone cabling

7.2.3.1 Component choice

The selection of balanced components will be determined by the channel lengths required and the class of applications to be supported. Refer to Annex F for guidance.

7.2.3.2 Dimensions

Figure 13 shows the model used to correlate cabling dimensions specified in this clause with the channel specifications in Clause 6. The backbone channel shown (either building or campus) contains a cross-connect at each end. This represents the maximum configuration for a Class D, E, E_A, F or F_A backbone channel.



EQP = equipment; C = connection (mated pair)

Figure 13 – Backbone cabling model

The channel includes additional cords comprising patch cords/jumpers and equipment cords.

In Table 34 it is assumed that:

- the flexible cable within these cords may have a higher insertion loss than that used in the backbone cable;
- all the cords in the channel have a common insertion loss specification.

In order to accommodate the higher insertion loss of cables used for patch cords, jumpers and equipment cords, the length of the cables used within a channel of a given class (see 5.7.9) shall be determined by the equations shown in Table 34.

The following general restrictions apply for Classes D, E, E_A, F and F_A:

- the physical length of channels shall not exceed 100 m;
- when 4 connections are used in a channel, the physical length of the backbone cable should be at least 15 m.

The maximum length of the backbone cable will depend on the total length of cords to be supported within a channel. The maximum lengths of cords shall be set during the design phase and a management system is required to ensure that these lengths are not exceeded during the operation of the cabling system.

Table 34 – Backbone channel length equations

Component Category	Implementation equations [a]							
	Class A	Class B	Class C	Class D	Class E	Class E_A	Class F	Class F_A
5	2 000	B = 250 – FX	B = 170 – FX	B = 105 – FX	–	–	–	–
6	2 000	B = 260 – FX	B = 185 – FX	B = 111 – FX	B = 105 – 3[b] – FX	–	–	–
6_A	2 000	B = 260 – FX	B = 189 – FX	B = 114 – FX	B = 108 – 3[b] – FX	B = 105 – 3[b] – FX	–	–
7	2 000	B = 260 – FX	B = 190 – FX	B = 115 – FX	B = 109 – 3[b] – FX	B = 107 – 3[b] – FX	B = 105 – 3[b] – FX	–
7_A	2 000	B = 260 – FX	B = 192 – FX	B = 117 – FX	B = 111 – 3[b] – FX	B = 110 – 3[b] – FX	B = 105 – 3[b] – FX	B = 110 – 3[b] – FX

B the maximum length of the backbone cable (m)

F combined length of patch cords/jumpers and equipment cords (m)

X the ratio of cord cable insertion loss (dB/m) to backbone cable insertion loss (dB/m)

NOTE 1 Where channels contain a different number of connections than in the model shown in Figure 13, the fixed cable length is reduced (where more connections exist) or increased (where fewer connections exist) by 2 m per connection for Category 5 cables and 1 m per connection for Category 6, 6_A, 7 and 7_A cables. Additionally, the *NEXT*, return loss (*RL*) and *ACR-F* performance should be verified.

NOTE 2 For operating temperatures above 20 °C, *B* should be reduced by 0,2 % per °C for screened cables; 0,4 % per °C (20 °C to 40 °C) and 0,6 % per °C (>40 °C to 60 °C) for unscreened cables.

[a] Applications limited by propagation delay or delay skew may not be supported if channel lengths exceed 100 m.

[b] This length reduction is to provide an allocated margin to accommodate insertion loss deviation.

8 Performance of optical fibre cabling

8.1 General

The selection of an optical fibre cabling channel design for use within a generic cabling system should be made with reference to Annex F. This standard specifies the following classes for optical fibre cabling:

Class OF-300 channels support applications over the cabled optical fibre Categories referenced in Clause 9 to a minimum of 300 m

Class OF-500 channels support applications over the cabled optical fibre Categories referenced in Clause 9 to a minimum of 500 m

Class OF-2 000 channels support applications over the cabled optical fibre Categories referenced in Clause 9 to a minimum of 2 000 m

Optical fibre cabling channels shall be comprised of components that comply with Clauses 9 and 10. These clauses specify physical construction (core/cladding diameter and numerical aperture) and transmission performance. Within the reference implementations of this clause, the cabled optical fibres used in each cabling channel shall be of the same specification.

8.2 Component choice

The selection of optical fibre components shall take into account the initial class of applications to be supported, and the required channel lengths, and should take into account any predicted changes to the class of applications to be supported during the expected life of the cabling.

The requirements for the wavelength multiplexing and demultiplexing components will be found in the application standards. There are no special requirements for generic cabling concerning wavelength multiplexing.

8.3 Channel attenuation

The channel attenuation shall not exceed the values shown in Table 35. The values are based on a total allocation of 1,5 dB for connecting hardware. Additional connectors and splices may be used if the power budget of the application allows. The attenuation of a channel shall be measured according to ISO/IEC TR 14763-3. The attenuation of channels and permanent links at a specified wavelength shall not exceed the sum of the specified attenuation values for the components at that wavelength (where the attenuation of a length of cabled optical fibre is calculated from its attenuation coefficient multiplied by its length).

Table 35 – Channel attenuation

Channel	Channel attenuation dB			
	Multimode		Single-mode	
	850 nm	1 300 nm	1 310 nm	1 550 nm
OF-300	2,55	1,95	1,80	1,80
OF-500	3,25	2,25	2,00	2,00
OF-2 000	8,50	4,50	3,50	3,50

8.4 Channel topology

The models of Figure 13 and Figure 14 are applicable to horizontal and backbone optical fibre cabling respectively. It should be noted that the connection system, used to terminate optical cabling, may contain mated connecting hardware and splices (permanent or re-useable) and that cross-connects may comprise re-useable splices.

The delivery of cabled optical fibre to the TO would not generally require transmission equipment at the FD (unless the design of optical fibre in the backbone cabling subsystem differs from that in the horizontal cabling subsystem). This allows the creation of a combined backbone/horizontal channel as shown in Figure 14. The three diagrams show a patched channel, a spliced channel and a direct channel (which does not require the use of a FD). Patched and spliced channel designs are also applicable to combined campus/building backbone channels and it is possible to consider a combined campus/building/horizontal channel.

The use of permanently spliced and direct channels may be used as a means of reducing channel attenuation and centralising the distribution of applications. However, centralising the distribution may also result in a reduction in the overall flexibility in generic cabling.

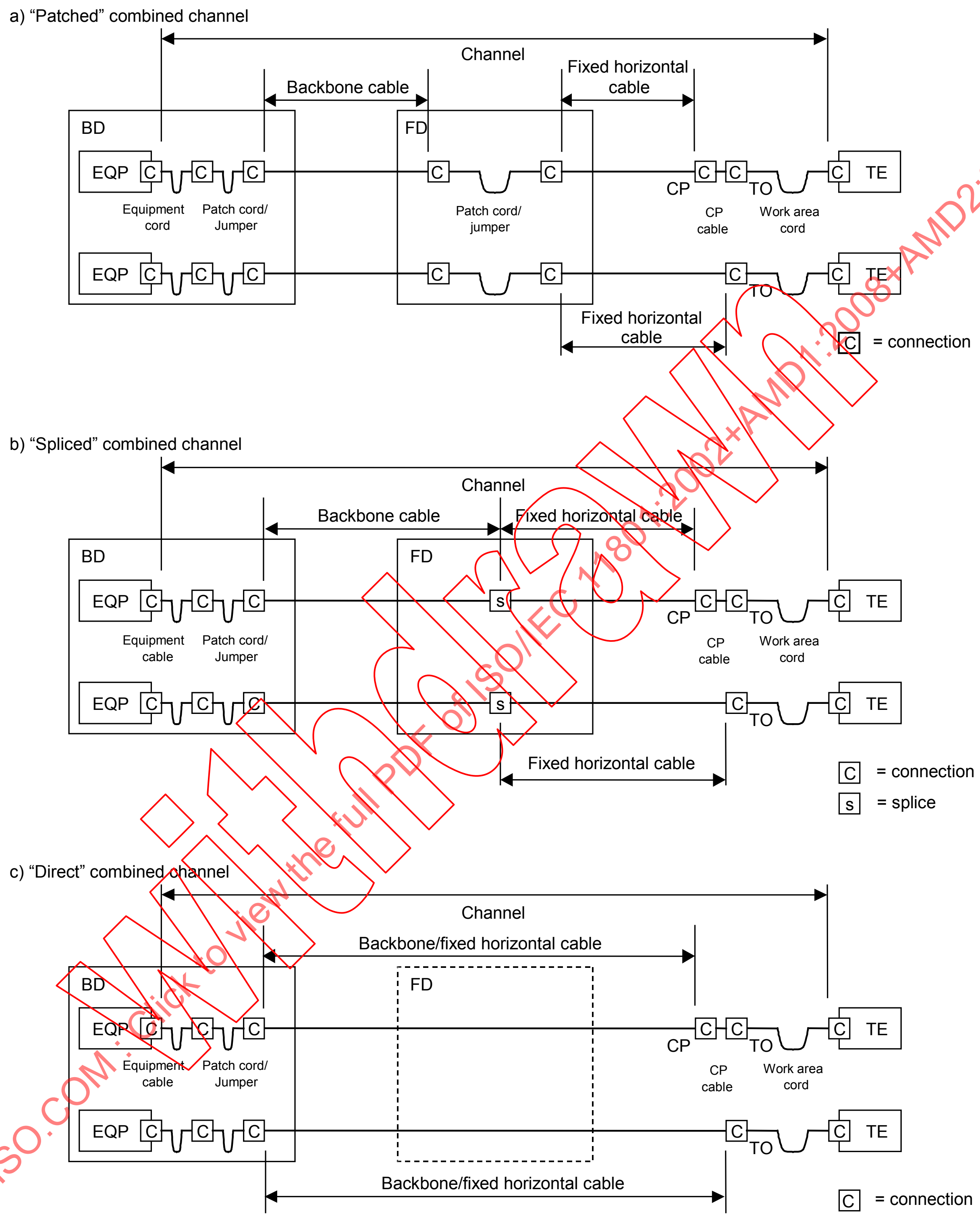


Figure 14 – Combined backbone/horizontal channels

In order to accommodate increased quantities of mated connections and splices used within a channel of a given class, the total length of the channel may have to be reduced to accommodate the additional attenuation.

8.5 Propagation delay

For some applications, knowledge of the delay of optical fibre cabling channels is important. This ensures compliance with end-to-end delay requirements of complex networks consisting of multiple cascaded channels. For this reason, it is important to know the lengths of the optical fibre cabling channels. It is possible to calculate propagation delay based on cable performance (see Clause 9).

9 Cable requirements

9.1 General

This clause specifies the minimum cable performance requirements for the reference implementations in Clause 7. The requirements in this clause are specified at a temperature of 20 °C. They include:

a) cables installed in the horizontal and backbone cabling subsystems specified in Clause 5 and used in the reference implementations of Clause 7 for balanced cabling and Clause 8 for optical fibre cabling;

b) balanced cables or cable elements to be used as jumpers;

c) balanced cables to be assembled as cords as specified in Clause 13 and used in the reference implementations of Clause 7.

Balanced cables shall be tested according to generic specification IEC 61156-1 and shall meet the requirements of 9.2.

Optical fibre cables shall meet the requirements of those parts of IEC 60794 that specify the relevant test methods and cable characteristics and that are referenced in 9.4.

9.2 Balanced cables

9.2.1 Performance for balanced cables

Both mechanical and electrical requirements are given in the generic specification IEC 61156-1 and the relevant sectional specifications and cover the minimum requirements to meet the performance classes specified in Clause 6 using the reference implementation of 7.2. The cables shall meet the requirements of Table 36. The Category 5 of this standard corresponds to the category 5e of the standards referenced in Table 36, if, in addition, the requirements of 9.2.2 are met.

Table 36 – Performance for balanced cables

IEC 61156-2, third edition [a]	Sectional specification for multicore and symmetrical pair/quad cables for digital communications – Horizontal wiring
IEC 61156-3, third edition [a]	Sectional specification for multicore and symmetrical pair/quad cables for digital communications – Work area wiring
IEC 61156-4 third edition [a]	Sectional specification for multicore and symmetrical pair/quad cables for digital communications – Riser cables
IEC 61156-5 second edition [a]	Symmetrical pair/quad cables for digital communications with transmission characteristics up to 1 000 MHz – Part 5: Horizontal wiring
IEC 61156-6 third edition [a]	Symmetrical pair/quad cables for digital communications with transmission characteristics up to 1 000 MHz – Part 6: Work area wiring

[a] In preparation, see Clause 2.

9.2.2 Additional requirements

9.2.2.1 General

The additional mechanical and electrical requirements given in this subclause shall be met. Measurements shall be performed according to IEC 61156-1. In case of conflict with referenced standards, the limits in this standard apply.

9.2.2.2 Mechanical characteristics of balanced cables

Table 37 – Mechanical characteristics of balanced cables

Cable characteristics		Units	Requirements
1.1	Diameter of conductor[a]	mm	0,4 to 0,8
1.2	Diameter over-insulated conductor[b]	mm	≤1,6
1.3	Outer diameter of backbone cable[c]	mm	≤90
1.4	Temperature range without mechanical or electrical degradation	°C	installation: 0 to +50 operation: –20 to +60
1.5	Minimum bending radius (after installation)[d]	25 mm for four-pair cables with a diameter up to 6 mm 50 mm for four-pair cables with a diameter over 6 mm	

[a] Conductor diameters below 0,5 mm and above 0,65 mm may not be compatible with all connecting hardware.
[b] Diameters over the insulated conductor up to 1,7 mm may be used if they meet all other performance requirements. These cables may not be compatible with all connecting hardware.
[c] Should be minimised to make best use of duct and cross-connect capacity (see Clause 10).
[d] For minimum bending radius requirements during installation refer to manufacturer's recommendations.

9.2.2.3 Characteristic impedance

Refer to 6.3.10 of IEC 61156-5:2009, measured according to 6.3.10.1.1 of IEC 61156-1:2007, on a standard length of 100 m. The nominal impedance shall be 100 Ω.

Alternative test methodologies that have been shown to correlate with these requirements may also be used.

9.2.2.4 Attenuation

For the attenuation of Category 5 cable the constants specified in 6.3.3.2 of IEC 61156-5:2009 shall be used. They result in a lower attenuation than given in Table 4 of 6.3.3.1 of IEC 61156-5:2009, for example in 21,3 dB/100 m at 100 MHz.

Calculations that result in attenuation below 4 dB shall revert to a requirement of 4 dB.

9.2.2.5 ACR-F and PS ACR-F

9.2.2.5.1 ACR-F

The *ACR-F* of each pair combination shall meet the requirements derived by the equation in Table 38.

Table 38 – ACR-F for cables

Frequency MHz	**Minimum ACR-F** [a, b] dB				
	Cable category				
	5	**6**	**6_A**	**7**	**7_A**
$1 \le f \le 100$	63,8 − 20 lg(*f*)	–	–	–	–
$1 \le f \le 250$	–	67,8 − 20 lg(*f*)	–	–	–
$1 \le f \le 500$	–	–	67,8 − 20 lg(*f*)	–	–
$1 \le f \le 600$	–	–	–	94,0 − 20 lg(*f*)	–
$1 \le f \le 1\,000$	–	–	–	–	105,3 − 20 lg(*f*)

[a] *ACR-F* at frequencies that correspond to measured *FEXT* values of greater than 70 dB, are for information only.

[b] *ACR-F* at frequencies that correspond to calculated values of greater than 75,0 dB shall revert to a minimum requirement of 75,0 dB.

Table 39 – Informative ACR-F values for cables at key frequencies

Frequency MHz	**Minimum ACR-F** dB				
	Cable category				
	5	**6**	**6_A**	**7**	**7_A**
1	63,8	67,8	67,8	75,0	75,0
100	23,8	27,8	27,8	54,0	65,3
250	–	19,8	19,8	46,0	57,3
500	–	–	13,8	40,0	51,3
600	–	–	–	38,4	49,7
1 000	–	–	–	–	45,3

9.2.2.5.2 PS ACR-F

The *PS ACR-F* of each pair combination shall meet the requirements derived by the equation in Table 40.

Table 40 – PS ACR-F for cables

Frequency MHz	Minimum PS ACR-F [a, b] dB Cable category				
	5	6	6_A	7	7_A
1 ≤ *f* ≤ 100	60,8 − 20 lg(*f*)	–	–	–	–
1 ≤ *f* ≤ 250	–	64,8 − 20 lg(*f*)	–	–	–
1 ≤ *f* ≤ 500	–	–	64,8 − 20 lg(*f*)	–	–
1 ≤ *f* ≤ 600	–	–	–	91,0 − 20 lg(*f*)	–
1 ≤ *f* ≤ 1 000	–	–	–	–	102,3 − 20 lg(*f*)

[a] *PS ACR-F* at frequencies that correspond to measured PS *FEXT* values of greater than 67 dB, are for information only.

[b] *PS ACR-F* at frequencies that correspond to calculated values of greater than 72,0 dB shall revert to a minimum requirement of 72,0 dB.

Table 41 – Informative PS ACR-F values for cables at key frequencies

Frequency MHz	Minimum PS ACR-F dB Cable category				
	5	6	6_A	7	7_A
1	60,8	64,8	64,8	72,0	72,0
100	20,8	24,8	24,8	51,0	62,3
250	–	16,8	16,8	43,0	54,3
500	–	–	10,8	37,0	48,3
600	–	–	–	35,4	46,7
1 000	–	–	–	–	42,3

9.2.2.6 Current carrying capacity

The minimum d.c. current carrying capacity shall be as indicated in Table 42.

Table 42 – Current carrying capacity for channel

Minimum current A d.c.	Operating temperature (*t*) °C
0,300	$t \leq (T_R - 10)$
0,175	$(T_R - 10) < t \leq T_R$
Where T_R is the lowest maximum operating temperature specified for the components comprising the cabling subsystem.	

Conformance shall be achieved by design.

Refer to ISO/IEC TR 29125 for additional information on current carrying capacity under different installation conditions.

9.2.2.7 Coupling attenuation

Screened cables shall meet the requirements of Type II as described in IEC 61156-5.

9.2.2.8 Transfer impedance

Screened cables shall meet the grade 2 transfer impedance requirements as described in IEC 61156-5.

9.2.2.9 Unbalance attenuation, near-end

Unscreened cables shall meet the requirements of level 2 as described in IEC 61156-5.

9.2.3 Additional performance requirements for flexible cables

This clause covers additional requirements for cables used for patch cords, for work area and for equipment cords for use with balanced cabling. The electrical performance of these cables shall meet the general requirements for balanced cables as specified in 9.2.2 for the respective category with exception of attenuation, d.c. loop resistance and return loss (*RL*), which are specified in this subclause.

The attenuation in dB/100 m and d.c. loop resistance shall not be more than 50 % higher than specified in 9.2.2. Consider 7.2 for additional length restrictions.

NOTE Return loss (*RL*) shall be measured on a test length of 100 m. Alternate test methodologies that have been shown to correlate with these requirements may also be used.

9.3 Additional crosstalk considerations for balanced cables

9.3.1 Cable sharing

Backbone cables required to support multiple signals shall meet the requirements of 9.3.2.

In the horizontal cabling subsystem, when multiple telecommunications outlets are served by a single cable, the near-end crosstalk of cable elements that extend to any two or more outlets shall meet the requirements of 9.3.3. The requirements of 9.3.3 also apply between units of hybrid and multi-unit cables used in either the horizontal or backbone subsystems.

9.3.2 Power summation in backbone cables

Examples of the types of cables covered by this clause include cables with two or more elements within a cable unit that are used for backbone subsystems. Cables according to the requirements of this clause shall meet the respective requirements of 9.2. These cables shall additionally meet the *PS NEXT* requirements for crosstalk in bundled cable, i.e. 3.3.10 of IEC 61156-5:2002[2].

NOTE 1 The specification in IEC 61156-5:2002 is more demanding by 2 dB than the original ISO/IEC requirement.

NOTE 2 PS NEXT takes the total crosstalk power into account. Therefore a higher count of adjacent pairs requires a higher pair-pair NEXT to achieve the same PS NEXT.

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2 IEC 61156-5:2002, *Multicore and symmetrical pair/quad cables for digital communications – Part 5: Symmetrical pair/quad cables with transmission characteristics up to 600 MHz – Horizontal floor wiring – Sectional specification*

9.3.3 Hybrid, multi-unit and cables connected to more than one TO

Examples of the types of cables that are covered by this clause include hybrid cables and multi-unit cables and any cable connected to more than one TO. The units may be of the same type or of different types, and of the same category or of different categories. Cables required to meet this clause shall also meet the requirements for the corresponding cable type given in 9.2.

For cables required to meet this clause, *PS NEXT* between any balanced cable unit or element shall meet the requirements specified in 3.3.10.1 of IEC 61156-5:2002.

NOTE 1 The above requirement is intended to minimise the potential for sheath sharing incompatibilities. Cables that meet the power summation requirement for *NEXT* may not support services with different signalling schemes. The use of different applications, supported by metallic cabling, with a maximum power budget exceeding 3 dB is not assured within a common sheath.

NOTE 2 The *PS NEXT* of cat. 6 is 1 dB more restrictive than needed to fulfil Clause 6 using the reference implementation of Clause 7.

9.3.4 Alien crosstalk

Cables used in class E_A and class F_A channels shall meet alien crosstalk requirements for category 6_A and category 7_A cables respectively, as specified in IEC 61156-5 and IEC 61156-6.

9.4 Optical fibre cable (cabled optical fibres)

9.4.1 Cabled optical fibre Categories

Six cabled optical fibre Categories are specified to support various classes of applications, four multimode Categories (OM1, OM2, OM3 and OM4) and two single-mode Categories (OS1 and OS2).

9.4.2 Generic performance requirements

9.4.2.1 Optical fibre cable attenuation

Table 43 – Cabled optical fibre attenuation

Cabled optical fibre attenuation (maximum) dB/km							
	OM1, OM2 OM3 and OM4 multimode		OS1 single-mode		OS2 single-mode		
Wavelength	850 nm	1 300 nm	1 310 nm	1 550 nm	1 310 nm	1 383 nm	1 550 nm
Attenuation	3,5	1,5	1,0	1,0	0,4	0,4	0,4

9.4.2.2 Propagation delay

A conservative conversion value for unit propagation delay of 5,00 ns/m (0,667 c) may be used. This value can be used to calculate channel delay without verification (see Clause 8).

9.4.3 Multimode optical fibre cable

Requirements of multimode optical fibre cables include compliance to

a) the cabled optical fibre performance,

b) the type of fibre,

c) the physical cable performance.

The cabled optical fibre Category designated as OM1 and OM2 is achieved using a multimode, graded-index optical fibre waveguide with nominal 50/125 µm or 62,5/125 µm core/cladding diameter and numerical aperture complying with A1b or A1a.1 optical fibre, respectively, of IEC 60793-2-10.

The cabled optical fibre Category designated as OM3 and OM4 is achieved using a multimode, graded-index optical fibre waveguide with nominal 50/125 µm core/cladding diameter and numerical aperture complying with A1a.2 and A1a.3 optical fibre respectively of IEC 60793-2-10.

The limits to be met for cabled optical fibre transmission performance are specified in Table 43 and Table 44. Attenuation shall be measured in accordance with IEC 60793-1-40.

The optical fibre cable shall meet mechanical and environmental requirements of the relevant specification of the IEC 60794 series.

Table 44 – Multimode optical fibre modal bandwidth

		Minimum modal bandwidth MHz × km		
		Overfilled launch bandwidth		**Effective modal bandwidth**
Wavelength		**850 nm**	**1 300 nm**	**850 nm**
Category	**Nominal core diameter** µm			
OM1	50 or 62,5	200	500	Not specified
OM2	50 or 62,5	500	500	Not specified
OM3	50	1 500	500	2 000
OM4	50	3 500	500	4 700

NOTE Modal bandwidth requirements apply to the optical fibre used to produce the relevant cabled optical fibre category and are assured by the parameters and test methods specified in IEC 60793-2-10. Optical fibres that meet only the overfilled launch modal bandwidth may not support some applications specified in Annex F.

9.4.4 Single-mode optical fibre cables

Requirements of single-mode optical fibre cables include compliance to

a) the cabled optical fibre performance,

b) the type of fibre,

c) the physical cable performance.

The cabled optical fibre category designated as OS1 is achieved using a single-mode, optical fibre waveguide complying with B1.1, B1.3 or B6_a, respectively, of IEC 60793-2-50.

The cabled optical fibre category designated as OS2 is achieved using a single-mode, optical fibre waveguide complying with B1.1, B1.3 or B6_a, respectively, of IEC 60793-2-50.

NOTE 1 If concatenating different OSx cabled optical fibres manufactured with different optical fibre types, refer to IEC/TR 62000:2010 for additional guidance.

The requirements for cabled optical fibre transmission performance are specified:

a) for the attenuation in Table 43 when measured in accordance with IEC 60793-1-40;

b) for the cut-off wavelength being less than 1 260 nm when measured in accordance with IEC 60793-1-44.

The optical fibre cable shall meet mechanical and environmental requirements of the relevant specification of the IEC 60794 series.

NOTE 2 Channels with a specified attenuation at 1 383 nm can only be created using B1.3 or B6_a optical fibres.

NOTE 3 B1.1 optical fibre is not recommended where channels may contain both category OS1 and OS2 cabled optical fibre.

NOTE 4 B6_a optical fibre is recommended when it is expected that the optical fibre or the cable will have to support smaller bend radii than 25 mm.

10 Connecting hardware requirements

10.1 General requirements

10.1.1 Applicability

This clause provides guidelines and requirements for connecting hardware used in generic cabling. For the purpose of this clause, a connector is a component normally attached to a cable or mounted on a piece of apparatus (excluding an adapter) for joining separable parts of a cabling system. Unless otherwise specified, this standard specifies the minimum performance of mated connectors as part of a link or channel. The requirements used in this clause apply to mated connections. The requirements of the detail specifications for free connectors and fixed connectors referenced in this clause shall also be met.

These requirements apply to individual connectors which include telecommunications outlets, patch panels, consolidation point connectors, splices and cross-connects. All requirements for these components are applicable for the temperature range of –10 °C to +60 °C. Performance requirements do not include the effects of cross-connect jumpers or patch cords. Requirements for balanced cords are provided in Clause 13.

NOTE This clause does not address requirements for devices with passive or active electronic circuitry, including those whose main purpose is to serve a specific application or to provide compliance with other rules and regulations. Examples include media adapters, impedance matching transformers, terminating resistors, LAN equipment, filters and protection apparatus. Such devices are considered to be outside the scope of generic cabling and may have significant detrimental effects on network performance. Therefore, it is important that their compatibility with the cabling system and equipment be considered before use.

10.1.2 Location

Connecting hardware is installed:

a) in a campus distributor permitting connections to building backbone and campus backbone cabling and equipment (if provided);

b) in a building distributor permitting connections to the backbone cabling and equipment (if provided);

c) in a floor distributor providing the cross-connections between backbone and horizontal cabling and permitting connections to equipment (if provided);

d) at the horizontal cabling consolidation point (if provided);

e) at the telecommunications outlet;

f) in the building entrance facility.

10.1.3 Design

In addition to its primary purpose, connecting hardware should be designed to provide

a) a means to identify cabling for installation and administration as described in Clause 12,

b) a means to permit orderly cable management,

c) a means of access to monitor or test cabling and equipment,

d) protection against physical damage and ingress of contaminants,

e) a termination density that is space efficient, but that also provides ease of cable management and ongoing administration of the cabling system,

f) a means to accommodate screening and bonding requirements, when applicable.

10.1.4 Operating environment

Performance of the connecting hardware shall be maintained over temperatures ranging from –10 °C to +60 °C. Connecting hardware should be protected from physical damage and from direct exposure to moisture and other corrosive elements. This protection may be accomplished by installation indoors or in an appropriate enclosure for the environment according to the relevant IEC standard.

10.1.5 Mounting

Connecting hardware should be designed to provide flexibility for mounting, either directly or by means of an adapter plate or enclosure. (For example, connecting hardware should have mounting provisions for placement on walls, in walls, in racks, or on other types of distribution frames and mounting fixtures.)

10.1.6 Installation practices

The manner and care with which the cabling is implemented are significant factors in the performance and ease of administration of installed cabling systems. Installation and cable management precautions should include the elimination of cable stress as caused by tension, sharp bends and tightly bunched cables.

The connecting hardware shall be installed to permit

a) minimal signal impairment and maximum screen effectiveness (where screened cabling is used) by proper cable preparation, termination practices (in accordance with manufacturer's guidelines) and well organised cable management,

b) room for mounting telecommunications equipment associated with the cabling system. Racks should have adequate clearances for access and cable dressing space.

The connecting hardware shall be identified according to the requirements of ISO/IEC 14763-2 (until ISO/IEC 14763-2 is published, relevant information can be found in ISO/IEC 14763-1). Planning and installation of connecting hardware should be carried out in accordance with ISO/IEC 14763-2 (until ISO/IEC 14763-2 is published, relevant information can be found in ISO/IEC TR 14763-2).

NOTE 1 See ISO/IEC 18010 for information on pathways and spaces for customer premises cabling.

NOTE 2 Some connections are used to perform a crossover function between two elements to properly configure cabling links for transmit and receive connections.

NOTE 3 Improper termination of any balanced cable element or screen may degrade transmission performance, increase emissions and reduce immunity.

10.1.7 Marking and colour coding

In order to maintain consistent and correct point-to-point connections, provisions shall be made to ensure that terminations are properly located with respect to connector positions and their corresponding cable elements. Such provisions may include the use of colours, alphanumeric identifiers or other means designed to ensure that cables are connected in a consistent manner throughout the system.

When two physically similar cabling types are used in the same subsystem, they shall be marked in such a way as to allow each cabling type to be clearly identified. For example, different performance categories, different nominal impedance and different optical fibre core diameters should carry unique markings or colours to facilitate visual identification.

10.2 Connecting hardware for balanced cabling

10.2.1 General requirements

The following requirements apply to all connecting hardware used to provide electrical connections with balanced cables that comply with the requirements of Clause 9. It is desirable that hardware used to directly terminate balanced cable elements be of the insulation piercing connection (IPC) type or the insulation displacement connection (IDC) type. In addition to these requirements, connecting hardware used with screened cabling shall be in full compliance with Clause 11.

The requirements of 10.2.3 and 10.2.4 are based upon the categories of connecting hardware specified in the reference implementations of Clause 7. For channel, permanent link, and CP link design routes to conformance, as specified in Clause 4, other connecting hardware can be used at places other than the TO.

10.2.2 Performance marking

Connecting hardware intended for use with balanced cabling should be marked to designate transmission performance at the discretion of the manufacturer. The markings, if any, shall be visible during installation and do not replace other markings specified in 10.1.7, or in Clause 12, or those required by local codes or regulations.

10.2.3 Mechanical characteristics

Connecting hardware intended for use with balanced cabling shall meet the requirements specified in Table 45.

Table 45 – Mechanical characteristics of connecting hardware for use with balanced cabling

	Mechanical characteristics		Requirement	Component or test standard
a)	Physical dimensions (TO only)	Category 5 unscreened	Mating dimensions and gauging	IEC 60603-7-2
		Category 5 screened	Mating dimensions and gauging	IEC 60603-7-3
		Category 6 unscreened	Mating dimensions and gauging	IEC 60603-7-4
		Category 6 screened	Mating dimensions and gauging	IEC 60603-7-5
		Category 6_A unscreened	Mating dimensions and gauging	IEC 60603-7-41
		Category 6_A screened	Mating dimensions and gauging	IEC 60603-7-51
		Category 7 screened	Mating dimensions and gauging	IEC 60603-7-7 [h]
		Category 7_A screened	Mating dimensions and gauging	IEC 60603-7-71 [h, i]
b)	Cable termination compatibility			
	Nominal conductor diameter – mm		0,5 to 0,65 [a]	–
	Cable type	Patching [d]	Stranded or solid conductors	–
		Jumpers	Stranded or solid conductors	–
		Other	Solid conductors	–
	Nominal diameter of insulated conductor mm	Categories 5 and 6	0,7 to 1,4 [b, c]	–
		Categories 6_A, 7, and 7_A	0,7 to 1,6 [b, c]	
	Number of conductors	Telecommunications outlet	8	Visual inspection
		Other	≥2 × n (n = 1, 2, 3, …)	
	Cable outer diameter mm	Outlet	≤20	–
		Free connector (plug)	≤9 [e]	
	Means to connect screen [f]		Mechanical and environmental performance	Annex C and Clause 11
c)	Mechanical operation (durability)			
	Cable termination (cycles)	Non-reusable IDC	1	IEC 60352-3 or IEC 60352-4
		Reusable IDC	≥20	IEC 60352-3 or IEC 60352-4
		Non-reusable IPC	1	IEC 60352-6
	Jumper termination (cycles)		≥200 [g]	IEC 60352-3 or IEC 60352-4
	TO-type interface (cycles)		≥750	IEC 60603-7 (unscreened) or IEC 60603-7-1 (screened)
	Other connections		≥200	Annex C

[a] It is not required that connecting hardware be compatible with cables outside of this range. However, when cables with conductor diameters as low as 0,4 mm or as high as 0,8 mm are used, special care shall be taken to ensure compatibility with connecting hardware to which they connect.

[b] Use of the free connector (plug) specified in series IEC 60603-7 is typically limited to cables having insulated conductor diameters in the range of 0,8 mm to 1,0 mm.

[c] It is not required that connecting hardware be compatible with cables outside of this range. However, when cables with insulated conductor diameters as high as 1,6 mm are used, special care shall be taken to ensure compatibility with connecting hardware to which they connect.

[d] Free connectors (plugs) shall be compatible with the solid or stranded cable selected for work area or equipment cords.

[e] Applicable only to individual cable units.

[f] If it is intended to use screened cabling, care should be taken that the connector is designed to terminate the screen. There may be a difference between connectors designed to terminate balanced cables with overall screens only, as opposed to cables having both individually screened elements and an overall screen (see ANNEX E).

[g] This durability requirement is only applicable to connections designed to administer cabling system changes (i.e., at a distributor).

[h] In installations where other factors, such as BCT applications (see ISO/IEC 15018), take preference over the backward compatibility offered with IEC 60603-7-7 and IEC 60603-7-71, the interface specified in IEC 61076-3-104 may be used.

[i] If backwards compatibility is not required, the free connector (plug) specified in IEC 61076-3-110 may be used.

10.2.4 Electrical characteristics

10.2.4.1 General

Connecting hardware intended for use with balanced cabling shall meet the following performance requirements. Connecting hardware shall be tested with terminations and test leads that match the nominal characteristic impedance of the types of cable that they are intended to terminate (see 9.2).

In the following tables, requirements are provided for a range of frequencies. Performance values at discrete frequencies are provided for reference only.

10.2.4.2 Telecommunications outlets

Telecommunications outlets of a given category shall meet the corresponding performance requirements provided in Table 46. In addition, connectors in all other locations having the same type of interface as the telecommunications outlet shall also comply with one or more of the standards specified in Table 46 with pair groupings as specified in 10.2.5. Requirements of 10.2.4.3 shall be met for all TOs.

Table 46 – Electrical characteristics of TOs intended for use with balanced cabling

Electrical characteristics of the telecommunications outlet		Requirement	Component or test standard
Interface type	Frequency range MHz		
Category 5 unscreened	d.c., 1 to 100	All	IEC 60603-7-2
Category 5 screened	d.c., 1 to 100	All	IEC 60603-7-3
Category 6 unscreened	d.c., 1 to 250	All	IEC 60603-7-4
Category 6 screened	d.c., 1 to 250	All	IEC 60603-7-5
Category 6_A unscreened	d.c., 1 to 500	All	IEC 60603-7-41
Category 6_A screened	d.c., 1 to 500	All	IEC 60603-7-51
Category 7 screened	d.c., 1 to 600	All	IEC 60603-7-7 [a]
Category 7_A screened	d.c., 1 to 1 000	All	IEC 60603-7-71 [a]

[a] In installations where other factors, such as BCT applications (see ISO/IEC 15018), take preference over the backward compatibility offered with IEC 60603-7-7, the interface specified in IEC 61076-3-104 may also be used.

10.2.4.3 Connecting hardware for use in distributors and consolidation points

Connecting hardware for use in distributors and consolidation points of a given category shall meet the corresponding performance requirements specified in the following tables irrespective of the mating interface used. All two-piece connections that are not covered by 10.2.4.2 shall comply with the mechanical and environmental performance requirements specified in Annex C for unscreened and screened connectors. All electrical requirements shall be met before and after mechanical and environmental performance testing, as prescribed in Annex C.

If the CP link portion of a Class F_A 3 connector permanent link (PL3 in Figure A.1) uses cable in accordance with IEC 61156-5, the connecting hardware at the CP requires NEXT and PSNEXT performance that is 6 dB better than the Category 7_A requirements specified in Table 51 and Table 53.

For connecting devices that provide cross-connections without patch cords or jumpers, electrical performance shall not be worse than the equivalent of two connectors and 5 m of patch cord of the same category. Applicable parameters include insertion loss, input to output resistance, input to output resistance unbalance, propagation delay, delay skew, and transfer impedance. In addition, crosstalk, return loss and unbalance attenuation (near end, TCL) of such devices shall not exceed 6 dB worse than the minimum values specified in the following tables. Cross-connections with "internal" switching that replaces jumpers or patch cords are an example of such devices.

Table 47 – Return loss for connector

Frequency MHz	Minimum return loss [a] dB					Test standard
	Connector category					
	5	**6**	**6_A**	**7**	**7_A**	
$1 \le f \le 100$	60 – 20 lg(f)	–	–	–	–	IEC 60512-25-5
$1 \le f \le 250$	–	64 – 20 lg(f)	–	–	–	
$1 \le f \le 500$	–	–	68 – 20 lg(f)	–	–	
$1 \le f \le 600$	–	–	–	68 – 20 lg(f)	–	
$1 \le f \le 1\,000$	–	–	–	–	68 – 20 lg(f) [b]	

[a] Return loss at frequencies that correspond to calculated values of greater than 30,0 dB shall revert to a minimum requirement of 30,0 dB.

[b] Calculated values below 10,0 dB revert to a 10,0 dB plateau.

Table 48 – Informative return loss values for connector at key frequencies

Frequency MHz	Minimum return loss dB				
	Connector category				
	5	**6**	**6_A**	**7**	**7_A**
1	30,0	30,0	30,0	30,0	30,0
100	20,0	24,0	28,0	28,0	28,0
250	–	16,0	20,0	20,0	20,0
500	–	–	14,0	14,0	14,0
600	–	–	–	12,4	12,4
1 000	–	–	–	–	10,0

Table 49 – Insertion loss for connector

Frequency MHz	Maximum insertion loss [a] dB					Test standard
	Connector category					
	5	**6**	**6_A**	**7**	**7_A**	
$1 \leq f \leq 100$	$0{,}04\sqrt{f}$	–	–	–	–	IEC 60512-25-2
$1 \leq f \leq 250$	–	$0{,}02\sqrt{f}$	–	–	–	
$1 \leq f \leq 500$	–	–	$0{,}02\sqrt{f}$	–	–	
$1 \leq f \leq 600$	–	–	–	$0{,}02\sqrt{f}$	–	
$1 \leq f \leq 1\,000$	–	–	–	–	$0{,}02\sqrt{f}$	

[a] Insertion loss at frequencies that correspond to calculated values of less than 0,1 dB shall revert to a requirement of 0,1 dB maximum.

Table 50 – Informative insertion loss values for connector at key frequencies

Frequency MHz	Maximum insertion loss dB				
	Connector category				
	5	**6**	**6_A**	**7**	**7_A**
1	0,10	0,10	0,10	0,10	0,10
100	0,40	0,20	0,20	0,20	0,20
250	–	0,32	0,32	0,32	0,32
500	–	–	0,45	0,45	0,45
600	–	–	–	0,49	0,49
1 000	–	–	–	–	0,63

Table 51 – Near end crosstalk (NEXT) for connector

Frequency MHz	Minimum NEXT [a] dB Connector category					Test standard
	5	6	6_A	7	7_A	
$1 \le f \le 100$	83 – 20 lg(f)	–	–	–	–	IEC 60512-25-1
$1 \le f \le 250$	–	94 – 20 lg(f)	94 – 20 lg(f)	–	–	
$250 < f \le 500$	–	–	46,04 – 30 lg(f/250)	–	–	
$1 \le f \le 600$	–	–	–	102,4 – 15 lg(f)	116,3 – 20 lg(f)	
$600 < f \le 1\ 000$	–	–	–	–	60,73 – 40 lg(f/600)	

[a] *NEXT* at frequencies that correspond to calculated values of greater than 75,0 dB shall revert to a minimum requirement of 75,0 dB.

Table 52 – Informative NEXT values for connector at key frequencies

Frequency MHz	Minimum NEXT dB Connector category				
	5	6	6_A	7	7_A
1	75,0	75,0	75,0	75,0	75,0
100	43,0	54,0	54,0	72,4	75,0
250	–	46,0	46,0	66,4	68,3
500	–	–	37,0	61,9	62,3
600	–	–	–	60,7	60,7
1 000	–	–	–	–	51,9

Table 53 – Power sum near end crosstalk (PS NEXT) for connector (for information only)

Frequency MHz	Minimum PS NEXT [a] dB Connector category					Test standard
	5	6	6_A	7	7_A	
$1 \le f \le 100$	80 – 20 lg(f)	–	–	–	–	IEC 60512-25-1
$1 \le f \le 250$	–	90 – 20 lg(f)	90 – 20 lg(f)	–	–	
$250 < f \le 500$	–	–	42,04 – 30 lg(f/250)	–	–	
$1 \le f \le 600$	–	–	–	99,4 – 15 lg(f)	113,3 – 20 lg(f)	
$600 < f \le 1\ 000$	–	–	–	–	57,73 – 40 lg(f/600)	

[a] *PS NEXT* at frequencies that correspond to calculated values of greater than 72,0 dB shall revert to a minimum requirement of 72,0 dB.

Table 54 – Informative PS NEXT values for connector at key frequencies

Frequency MHz	Minimum PS NEXT dB				
	Connector category				
	5	6	6_A	7	7_A
1	72,0	72,0	72,0	72,0	72,0
100	40,0	50,0	50,0	69,4	72,0
250	–	42,0	42,0	63,4	65,3
500	–	–	33,0	58,9	59,3
600	–	–	–	57,7	57,7
1 000	–	–	–	–	48,9

Table 55 – Far end crosstalk (FEXT) for connector

Frequency MHz	Minimum FEXT [a, b] dB					Test standard
	Connector category					
	5	6	6_A	7	7_A	
$1 \le f \le 100$	75,1 − 20 lg(f)	–	–	–	–	IEC 60512-25-1
$1 \le f \le 250$	–	83,1 − 20 lg(f)	–	–	–	
$1 \le f \le 500$	–	–	83,1 − 20 lg(f)	–	–	
$1 \le f \le 600$	–	–	–	90 − 15 lg(f)	–	
$1 \le f \le 1\,000$	–	–	–	–	103,9 − 20 lg(f)	

[a] *FEXT* at frequencies that correspond to calculated values of greater than 75,0 dB shall revert to a minimum requirement of 75,0 dB.

[b] For connectors, the difference between *FEXT* and *ACR-F* is minimal. Therefore, connector *FEXT* requirements are used to model *ACR-F* performance for links and channels.

Table 56 – Informative FEXT values for connector at key frequencies

Frequency MHz	**Minimum FEXT** dB				
	Connector category				
	5	**6**	**6_A**	**7**	**7_A**
1	75,0	75,0	75,0	75,0	75,0
100	35,1	43,1	43,1	60,0	63,9
250	–	35,1	35,1	54,0	55,9
500	–	–	29,1	49,5	49,9
600	–	–	–	48,3	48,3
1 000	–	–	–	–	43,9

Table 57 – Power sum far end crosstalk (PS FEXT) for connector (for information only)

Frequency MHz	**Minimum PS FEXT** [a, b] dB					**Test standard**
	Connector category					
	5	**6**	**6_A**	**7**	**7_A**	
$1 \le f \le 100$	72,1 - 20 lg(*f*)	–	–	–	–	IEC 60512-25-1
$1 \le f \le 250$	–	80,1 - 20 lg(*f*)	–	–	–	
$1 \le f \le 500$	–	–	80,1 - 20 lg(*f*)	–	–	
$1 \le f \le 600$	–	–	–	87 - 15 lg(*f*)	–	
$1 \le f \le 1\ 000$	–	–	–	–	100,9 - 20 lg(*f*)	

[a] *PS FEXT* at frequencies that correspond to calculated values of greater than 72,0 dB shall revert to a minimum requirement of 72,0 dB.

[b] For connectors, the difference between *PS FEXT* and *PS ACR-F* is minimal. Therefore, connector *PS FEXT* requirements are used to model *PS ACR-F* performance for links and channels.

Table 58 – Informative PS FEXT values for connector at key frequencies

Frequency MHz	**Minimum PS FEXT** dB				
	Connector category				
	5	**6**	**6_A**	**7**	**7_A**
1	72,0	72,0	72,0	72,0	72,0
100	32,1	40,1	40,1	57,0	60,9
250	–	32,1	32,1	51,0	52,9
500	–	–	26,1	46,5	46,9
600	–	–	–	45,3	45,3
1 000	–	–	–	–	40,9

Table 59 – Input to output resistance

Frequency	Maximum input to output resistance mΩ					Test standard
	Connector category					
	5	6	6_A	7	7_A	
d.c.	200	200	200	200	200	IEC 60512-2-1 Test 2a

Table 60 – Input to output resistance unbalance

Frequency	Maximum input to output resistance unbalance mΩ					Test standard
	Connector category					
	5	6	6_A	7	7_A	
d.c.	50	50	50	50	50	IEC 60512-2-1 Test 2a

Table 61 – Current carrying capacity

Frequency	Minimum current carrying capacity [a, b] A					Test standard
	Connector category					
	5	6	6_A	7	7_A	
d.c.	0,75	0,75	0,75	0,75	0,75	IEC 60512-5-2 Test 5b

[a] Applicable for an ambient temperature of 60 °C.

[b] Applicable to each conductor including the screen, if present.

Table 62 – Propagation delay

Frequency MHz	Maximum propagation delay ns					Test standard
	Connector category					
	5	6	6_A	7	7_A	
$1 \leq f \leq 100$	2,5	–	–	–	–	IEC 60512-25-4
$1 \leq f \leq 250$	–	2,5	–	–	–	
$1 \leq f \leq 500$	–	–	2,5	–	–	
$1 \leq f \leq 600$	–	–	–	2,5	–	
$1 \leq f \leq 1\,000$	–	–	–	–	2,5	

This parameter shall be met by design.

Table 63 – Delay skew

Frequency MHz	Maximum delay skew ns					Test standard
	Connector category					
	5	6	6_A	7	7_A	
$1 \le f \le 100$	1,25	–	–	–	–	IEC 60512-25-4
$1 \le f \le 250$	–	1,25	–	–	–	
$1 \le f \le 500$	–	–	1,25	–	–	
$1 \le f \le 600$	–	–	–	1,25	–	
$1 \le f \le 1\ 000$	–	–	–	–	1,25	
This parameter shall be met by design.						

Table 64 – Transverse conversion loss (TCL)

Frequency MHz	Minimum transverse conversion loss (*TCL*) [a] dB					Test standard
	Connector category					
	5	6	6_A	7	7_A	
$1 \le f \le 100$	66 − 20 lg(f)	–	–	–	–	ITU-T Recommendation O.9
$1 \le f \le 250$	–	68 − 20 lg(f)	–	–	–	
$1 \le f \le 500$	–	–	68 − 20 lg(f)	–	–	
$1 \le f \le 600$	–	–	–	68 − 20 lg(f)	–	
$1 \le f \le 1\ 000$	–	–	–	–	68 − 20 lg(f)	

[a] *TCL* at frequencies that correspond to calculated values of greater than 50,0 dB shall revert to a minimum requirement of 50,0 dB.

Table 65 – Informative TCL values for connector at key frequencies

Frequency MHz	Minimum transverse conversion loss (*TCL*) dB				
	Connector category				
	5	6	6_A	7	7_A
1	50,0	50,0	50,0	50,0	50,0
100	26,0	28,0	28,0	28,0	28,0
250	–	20,0	20,0	20,0	20,0
500	–	–	14,0	14,0	14,0
600	–	–	–	12,4	12,4
1 000	–	–	–	–	8,0

Table 66 – Transverse conversion transfer loss (TCTL)

Frequency MHz	Minimum transverse conversion transfer loss (*TCTL*) [a] dB					Test standard
	Connector category					
	5	6	6_A	7	7_A	
1 ≤ *f* ≤ 100	66 – 20 lg(*f*)	–	–	–	–	ITU-T Recommendation O.9
1 ≤ *f* ≤ 250	–	68 – 20 lg(*f*)	–	–	–	
1 ≤ *f* ≤ 500	–	–	68 – 20 lg(*f*)	–	–	
1 ≤ *f* ≤ 600	–	–	–	68 – 20 lg(*f*)	–	
1 ≤ *f* ≤ 1 000	–	–	–	–	68 – 20 lg(*f*)	

[a] *TCTL* at frequencies that correspond to calculated values of greater than 50,0 dB shall revert to a minimum requirement of 50,0 dB.

Table 67 – Informative TCTL values for connector at key frequencies

Frequency MHz	Minimum transverse conversion loss (*TCTL*) dB				
	Connector category				
	5	6	6_A	7	7_A
1	50,0	50,0	50,0	50,0	50,0
100	26,0	28,0	28,0	28,0	28,0
250	–	20,0	20,0	20,0	20,0
500	–	–	14,0	14,0	14,0
600	–	–	–	12,4	12,4
1 000	–	–	–	–	8,0

Table 68 – Transfer impedance (screened connectors only)

Frequency MHz	Maximum transfer impedance Ω					Test standard
	Connector category					
	5	6	6_A	7	7_A	
1 ≤ *f* ≤ 10	$0,1\,f^{0,3}$	$0,1\,f^{0,3}$	$0,1\,f^{0,3}$	$0,05\,f^{0,3}$	$0,05\,f^{0,3}$	IEC 60512-26-100
10 < *f* ≤ 80	0,02 *f*	0,02 *f*	0,02 *f*	0,01 *f*	0,01 *f*	Test 26e

Table 69 – Informative transfer impedance values (screened connectors only) at key frequencies

Frequency MHz	Maximum transfer impedance Ω				
	Connector category				
	5	6	6_A	7	7_A
1	0,10	0,10	0,10	0,05	0,05
10	0,20	0,20	0,20	0,10	0,10
80	1,60	1,60	1,60	0,80	0,80

Table 70 – Coupling attenuation (screened connectors only)

Frequency MHz	**Minimum coupling attenuation** dB					**Test standard**
	Connector category					
	5	**6**	**6$_A$**	**7**	**7$_A$**	
30 ≤ f ≤ 100	≥45,0	≥45,0	≥45,0	≥45,0	≥45,0	IEC 62153-4-12
100 < f ≤ NOTE	–	85-20 lg(f)	85-20 lg(f)	85-20 lg(f)	85-20 lg(f)	

NOTE Coupling attenuation is measured to 1 000 MHz but the limit applies to the upper frequency of the Category under test.

Table 71 – Informative coupling attenuation values (screened connectors only) at key frequencies

Frequency MHz	**Minimum coupling attenuation** dB				
	Connector category				
	5	**6**	**6$_A$**	**7**	**7$_A$**
30	45,0	45,0	45,0	45,0	45,0
100	45,0	45,0	45,0	45,0	45,0
250	–	37,0	37,0	37,0	37,0
500	–	–	31,0	31,0	31,0
600	–	–	–	29,4	29,4
1 000	–	–	–	–	25,0

Table 72 – Insulation resistance

Frequency	**Minimum insulation resistance** MΩ					**Test standard**
	Connector category					
	5	**6**	**6$_A$**	**7**	**7$_A$**	
d.c.	100	100	100	100	100	IEC 60512-3-1 Test 3a, Method C 500 V d.c.

Table 73 – Voltage proof

Electrical characteristics	**Frequency**	**Minimum voltage proof** V					**Test standard**
		Connector category					
		5	**6**	**6$_A$**	**7**	**7$_A$**	
Conductor to conductor	d.c.	1 000	1 000	1 000	1 000	1 000	IEC 60512-4-1 Test 4a
Conductor to test panel (and screen, if present)	d.c.	1 500	1 500	1 500	1 500	1 500	

Table 74 – Power sum alien near end crosstalk (PS ANEXT)

Frequency MHz	Minimum power sum alien near end crosstalk (PS ANEXT) [a] dB		Test standard
	Connector category		
	6A	7A	
1 ≤ *f* ≤ 500	110,5 − 20lg(*f*)	–	IEC 60512-25-9
1 ≤ *f* ≤ 1 000	–	125,5 − 20lg(*f*)	

• *PS ANEXT* at frequencies that correspond to calculated values of greater than 72,0 dB shall revert to a minimum requirement of 72,0 dB.

Table 75 – Informative PS ANEXT values at key frequencies

Frequency MHz	Minimum power sum alien near end crosstalk (PS ANEXT) dB	
	Connector category	
	6A	7A
1	72,0	72,0
100	70,5	72,0
250	62,5	72,0
500	56,5	71,5
1 000	–	65,5

Table 76 – Power sum alien far end crosstalk (PS AFEXT)

Frequency MHz	Minimum power sum alien far end crosstalk (PS AFEXT) [a, b] dB		Test standard
	Connector category		
	6A	7A	
1 ≤ *f* ≤ 500	107 − 20 lg(*f*)	–	IEC 60512-25-9
1 ≤ *f* ≤ 1 000	–	122 − 20 lg(*f*)	

[a] *PS AFEXT* at frequencies that correspond to calculated values of greater than 72,0 dB shall revert to a minimum requirement of 72,0 dB.

[b] For connectors, the difference between *PS AFEXT* and *PS AACR-F* is minimal. Therefore, connector *PS AFEXT* requirements are used to model *PS AACR-F* performance for links and channels.

Table 77 – Informative PS AFEXT values at key frequencies

Frequency MHz	**Minimum power sum alien far end crosstalk (PS AFEXT)** dB	
	Connector category	
	6_A	**7_A**
1	72,0	72,0
100	67,0	72,0
250	59,0	72,0
500	53,0	68,0
1 000	–	62,0

10.2.5 TO requirements

For all cabling classes, each horizontal balanced cable shall be terminated at the telecommunications outlet with an unkeyed fixed connector (jack) that meets the specifications of 10.2.3 and 10.2.4. Pin and pair grouping assignments shall be as shown in Figure 15, Figure 16 or Figure 17.

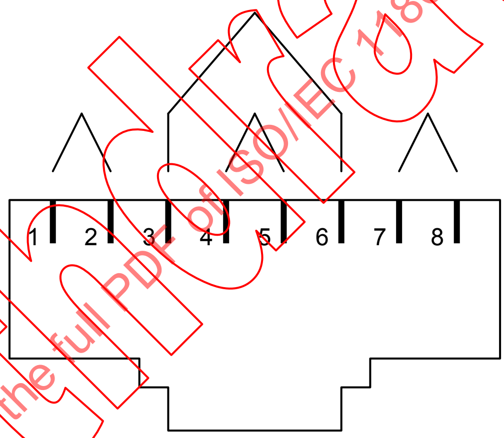
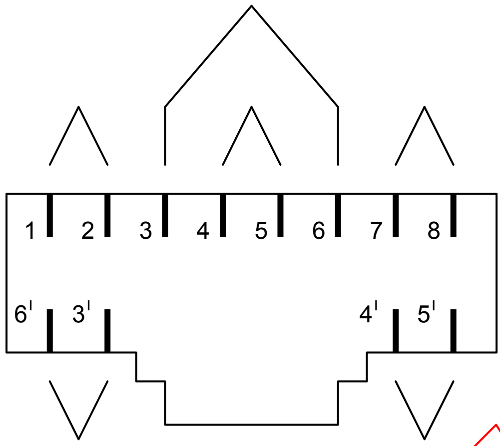


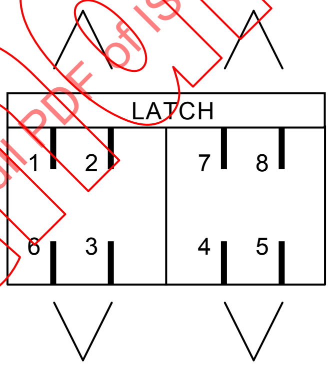
Figure 15 – Pin grouping and pair assignments for IEC 60603-7 series interface for Categories 5, 6 and 6_A (front view of fixed connector (jack), not to scale)



NOTE 1 Pin designations 1, 2, 3', 4', 5', 6', 7 and 8 are used for Categories 7 and 7_A and correspond to pin designations 1, 2, 3, 4, 5, 6, 7 and 8 for categories 5, 6, and 6_A.

NOTE 2 Figure 16 shows front view of fixed connector (jack), not to scale.

Figure 16 – Pin grouping and pair assignment for the IEC 60603-7 series interface for Categories 7 and 7_A



NOTE 1 Pin designations correspond to those of the IEC 60603-7 series interface.

NOTE 2 Figure 17 shows front view of fixed connector (jack), not to scale.

Figure 17 – Pin grouping and pair assignments for Categories 7 and 7_A (IEC 61076-3-104) interface

If different connecting hardware types are used at a distributor, CP or TO in the same link or channel the cabling connections shall be configured with consistent pin/pair assignments to ensure end-to-end connectivity. Pair rearrangement at the telecommunications outlet should not involve modification of the horizontal cable terminations. If pair rearrangement is used at the telecommunications outlet, the configuration of the outlet terminations shall be clearly identified.

Free and fixed connectors (plugs and jacks) that are intermateable shall be backward compatible with those of different performance categories. Backward compatibility means that the mated connections with free and fixed connectors (plugs and jacks) from different categories shall meet all of the requirements for the lower category component. See Table 78 for a matrix of backward compatible mated free and fixed connectors (plug and jack) performance that is representative of backward compatible connectivity.

Table 78 – Matrix of backward compatible mated free and fixed connector (plug and jack) performance

		Fixed connector (jack) performance at the TO				
		Category 5	**Category 6**	**Category 6_A**	**Category 7**	**Category 7_A**
Free connector (plug)	**Category 5**	Category 5	Category 5	Category 5	Category 5	Category 5
	Category 6	Category 5	Category 6	Category 6	Category 6	Category 6
	Category 6_A	Category 5	Category 6	Category 6_A	Category 6_A	Category 6_A
	Category 7	Category 5	Category 6	Category 6_A	Category 7	Category 7
	Category 7_A	Category 5	Category 6	Category 6_A	Category 7	Category 7_A

NOTE 1 When two physically similar cabling links are used in the same installation, special precautions are required to ensure that they are properly identified at the telecommunications outlet. Examples of when such identification is necessary would include different performance classes or cables with different nominal impedance. See also Clause 12.

NOTE 2 For proper connectivity, care is needed to ensure that pairs are terminated consistently at the telecommunications outlet and floor distributor. If pairs are terminated on different positions at the two ends of a link, although DC continuity may be maintained, through connectivity will be lost. See Clause 12 for cabling system administration.

10.2.6 Design considerations for installation

Connecting hardware should be designed in such a way that the untwisted length in a cable element, resulting from its termination to connecting hardware is as short as possible.

Connecting hardware should permit a minimum length of exposed pairs between the end of the cable sheath and the point of termination. In addition, only the length of cable sheath required for termination and trimming should be removed or stripped back. These recommendations are provided to minimise the impact of terminations on transmission performance and are not intended to constrain twist length for cable or jumper construction.

Earthing requirements and screen continuity considerations are specified in Clause 11.

10.3 Optical fibre connecting hardware

10.3.1 General requirements

The requirements of 10.3.2 through 10.3.5 apply to all connecting hardware used to provide connections between optical fibre cables described in Clause 9 with the following exception. The requirements of 10.3.4 and Table 79, item a) apply to the telecommunications outlet only.

Optical fibre adapters and connectors should be protected from dust and other contaminants, specifically while they are in an unmated state. End faces of connectors shall be inspected according to ISO/IEC 14763-3 and subsequently cleaned when necessary, prior to connection.

10.3.2 Marking and colour coding

Consistent coding of connectors and adapters, for example by colour, should be used to identify connections between:

- different cabled multimode optical fibre types;
- incompatible single-mode connecting hardware (e.g. blue for connectors with PC ferrules and green for connectors with APC ferrules).

In addition, keying and the identification of optical fibre positions may be used to ensure that correct polarity is maintained for duplex links.

NOTE 1 These markings are in addition to, and do not replace, other markings specified in Clause 12, or those required by local codes or regulations.

NOTE 2 The following colour codes apply to IEC 60874-19-1 SC duplex and IEC 60874-14[3] SC simplex connectors but may also be used for other connector types:

Multimode 50 µm and 62,5 µm:	Beige or black
Single-mode PC:	Blue
Single-mode APC:	Green

10.3.3 Mechanical and optical characteristics

Optical fibre connecting hardware shall meet the requirements of Table 79. All connections not covered by 10.3.4 shall comply with at least the equivalent optical, mechanical and environmental performance requirements specified in IEC 60874-19-1.

3 IEC 60874-14, *Connectors for optical fibres and cables – Part 14: Sectional specification for fibre optic connector – Type SC.* This publication has been withdrawn in 2002, but can still be ordered if needed.

Table 79 – Mechanical and optical characteristics of optical fibre connecting hardware

	Mechanical and optical characteristics		Requirement	Component or test standard
a)	Physical dimensions (only at telecommunications outlet) [a]		Mating dimensions and gauging	IEC 61754-20, interface 5
b)	Cable termination compatibility			
	Nominal cladding diameter µm		125	IEC 60793-2, Clause 5 (A1a, A1b) and 32.2 (B1)
	Nominal buffer diameter mm		–	IEC 60794-2, 6.1
	Cable outer diameter mm		–	IEC 60794-2, 6.1
c)	Mechanical endurance (durability) cycles		≥500	IEC 61300-2-2
d)	Mated pair transmission performance			
	Maximum insertion loss [b] dB	Other	100% ≤ 0,75 dB 95% ≤ 0,50 dB 50% ≤ 0,35 dB	IEC 61300-3-34
		Splice	0,3	IEC 61073-1
	Minimum return loss dB	Multimode	20	IEC 61300-3-6
		Single-mode	35	

[a] See 10.3.4.

[b] Insertion loss of splices and connectors shall be met with the referenced test method where the optical source produces a controlled launch condition. The required metric to qualify the source is encircled flux. The required launch condition is specified in IEC 61300-1 and shall be based on LED. Under filling sources such as lasers will produce lower insertion loss values.

10.3.4 TO requirements

The optical fibre cables in the work area shall be connected to horizontal cabling at the TO with a duplexable LC connector that complies with IEC 61754-20.

Networks having an installed base of IEC 60874-19-1 (SC-D) connectors and adapters may remain with the SC-D connector and adaptor for both existing and future additions to their optical fibre network. (For mating dimensions and gauging of multimode, see IEC 60874-19-3, and of single-mode, see IEC 60874-19-2.)

The optical fibre connector used at the TO shall meet the requirements of 10.3.3.

10.3.5 Connection schemes for optical fibre cabling

10.3.5.1 General

Consistent polarity of duplex optical fibre connections shall be maintained throughout the cabling system by means of physical keying, administration (i.e., labelling) or both. The following guidelines are provided to ensure that properly installed connectors and adapters provide a functional and maintainable optical fibre cabling system. Consult with equipment manufacturers and system integrators to determine the suitability of these guidelines for specific networking applications. Additionally, all optical ports should comply with IEC 60825.

To ensure maximum flexibility on the cabling side of TOs and distributor panels a simplex connector is recommended for the termination of horizontal and backbone optical cables as illustrated in Figure 19.

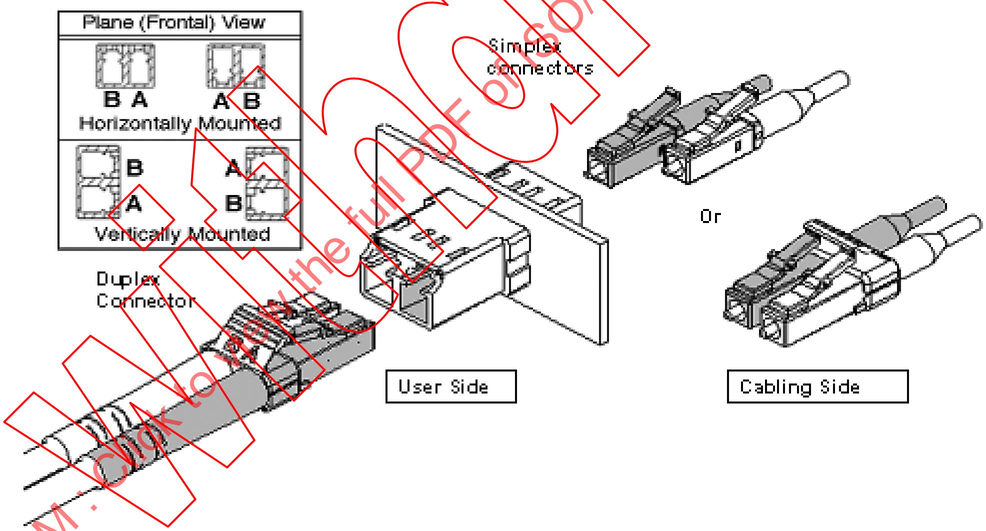
On the work area side of TOs and the interconnect/cross-connect side of distributor panels, a duplex presentation maintains the correct polarity of transmit and receive optical fibres in two optical fibre transmission systems while still allowing transmission systems using other optical fibre counts. At the distributor, this presentation is preferably a duplex adapter that maintains the spacing and alignment as specified in IEC 61754-20 interface 5.

Polarity is defined at the TO for optical fibre positions A and B. To extend this polarity throughout the cabling system, it is important that the same orientation, colour coding, marking, and optical fibre configuration be applied consistently. Once the system is installed and correct polarity is verified, the correct polarity of transmit and receive optical fibres within the optical fibre cabling system will be maintained.

10.3.5.2 Connectivity options at the TO

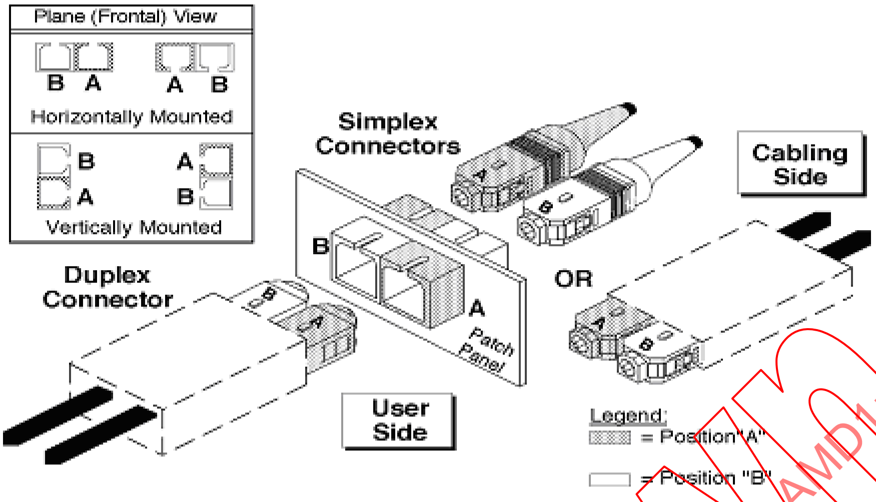
Where there is no installed base of optical fibre cabling, the LC connectivity is specified at the TO and should provide a means to identify the polarity by any combination of latching, keying, or labelling. See an example in Figure 18.

Where premises have an installed base of SC-D connectivity, additional TO connections may be made using SC-D connectivity provided their keys are oriented as in Figure 19.



NOTE Shading and A/B markings are for information only.

Figure 18 – Duplex-able LC connectivity configuration with an example of polarity identification



NOTE Shading and A/B markings are for information only.

Figure 19 – Duplex SC connectivity configuration

10.3.5.3 Connectivity options at other locations

Polarity at locations other than the TO may be maintained by the strict control of changes to the connectivity at distributors and CPs, or by adopting the configurations detailed in 10.3.5.2. Connectors at locations other than the TO shall meet the optical, mechanical, and environmental requirements stated in IEC 60874-19-1, although they may have other mating interfaces.

10.3.5.4 Other duplex connectors

Alternative connector designs shall employ similar labelling and identification schemes to the duplex LC and SC. Position A and B on alternative duplex connector designs shall be in the same position as in Figure 19. For alternative connector designs utilising latches, the latch defines the positioning in the same manner as the key and keyways.

10.3.5.5 Cord termination configuration

It is recommended that connection of patch cords and equipment cords to the duplex adapter be made by means of a duplex connector assembly.

Optical fibre patch cords, whether they are used for cross-connection or interconnection to equipment, shall be of a cross-over orientation such that Position A goes to Position B on one optical fibre, and Position B goes to Position A on the other optical fibre of the optical fibre pair (Figure 20). Each end of the optical fibre patch cord shall be identified to indicate Position A and Position B if the connector can be separated into its simplex components. For alternate connector designs utilising latches, the latch defines the positioning in the same manner as the keys.

For simplex connectors, the connector that plugs into the receiver shall be considered Position A, and the connector that plugs into the transmitter shall be considered Position B.

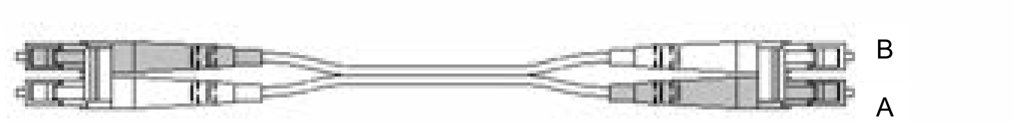


Figure 20 – Optical fibre cord

11 Screening practices

NOTE When ISO/IEC 14763-2 is published the content of Clause 11 will be obsolete, and superseded by the content included in ISO/IEC 14763-2.

11.1 General

This clause applies when screened cables or cables with screened elements or units are used. Only basic guidance is provided. The procedures necessary to provide adequate earthing for both electrical safety and EM performance are subject to national and local regulations, always to proper workmanship in accordance with ISO/IEC 14763-2 (until ISO/IEC 14763-2 is published, relevant information can be found in ISO/IEC TR 14763-2), and in certain cases to installation specific engineering. Some cabling employs components that utilise screening for additional crosstalk performance and is therefore also subject to screening practices. Note that a proper handling of screens in accordance with ISO/IEC 14763-2 (until ISO/IEC 14763-2 is published, relevant information can be found in ISO/IEC TR 14763-2) and suppliers' instructions will increase performance and safety.

11.2 Electromagnetic performance

Cabling screens should be properly bonded to earth for electrical safety and to optimise EM performance. All cabling components which form part of a screened channel should be screened and meet the screening requirements given in Clauses 9 and 10. Screened cabling links shall meet cabling screening requirements given in 6.4. Cable screens shall be terminated to connector screens by low impedance terminations sufficient to maintain screen continuity necessary to meet cabling screening requirements. Suppliers' instructions as how to make low impedance terminations shall be asked for and observed. Work area, equipment cords and the equipment attachment should be screened and if so, shall provide screen continuity.

11.3 Earthing

Earthing and bonding shall be in accordance with applicable electrical codes or IEC 60364-1. All screens of the cables shall be bonded at each distributor. Normally, the screens are bonded to the equipment racks, which are, in turn, bonded to building earth.

NOTE High working frequencies and/or high frequencies of parasitic currents or fields require earthing with low impedance, which may be realised with a meshed system.

The bond shall be designed to ensure that

a) The path to earth shall be permanent, continuous and of low impedance. It is recommended that each equipment rack is individually bonded, in order to assure the continuity of the earth path.

b) The cable screens provide a continuous earth path to all parts of a cabling system that are interconnected by it.

This bonding ensures that voltages that are induced into cabling (by any disturbances from power lines or any other disturbers) are directed to building earth, and so do not cause interference to the transmitted signals. All earthing electrodes to different systems in the building shall be bonded together to reduce effects of differences in earth potential. The building earthing system should not exceed the earth potential difference limits of 1 V r.m.s. between any two earths on the network.

12 Administration

Administration is an essential aspect of generic cabling. The flexibility of generic cabling can be fully exploited only if the cabling and its use is properly administered. Administration involves accurate identification and record keeping of all the components that comprise the cabling system as well as the pathways, distributors and other spaces in which it is installed. All changes to the cabling should be recorded when they are carried out. Computer based administration of records is strongly recommended for larger installations.

Telecommunications cabling administration shall comply with ISO/IEC 14763-2 (until ISO/IEC 14763-2 is published, relevant information can be found in ISO/IEC 14763-1).

NOTE When ISO/IEC 14763-2 is published, the content of Clause 12 will be obsolete, and superseded by the content of ISO/IEC 14763-2.

13 Balanced cords

13.1 Introduction

This clause covers balanced cords constructed with balanced cables as specified in the IEC 61156 series and two free connectors (plugs) as specified in Clause 10. The components used in these cords shall meet the requirements of Clauses 9 and 10 respectively. The cable used to make balanced cords shall meet the requirements of IEC 61156-5 or IEC 61156-6 for the corresponding category. The purpose of cords is to connect to connecting hardware that utilises fixed connectors (jacks) that are also defined in Clause 10. Compliance to transmission parameters that are not specified in this clause are considered to be met by design.

NOTE It is assumed that cords that use connectors with interfaces other than the IEC 60603-7 series also meet the requirements of this clause.

Connecting hardware performance is subject to influence by the properties of the plug termination and therefore cords should be tested to determine the quality of the assembly. This clause specifies the minimum requirements for cords. The test methods and mechanical stresses are specified in IEC 61935-2. All requirements of this clause have to be met after first exposing the device under test to the mechanical stress. Cords shall meet the electrical and mechanical requirements of IEC 61935-2.

13.2 Insertion loss

Insertion loss (*IL*) of cords shall not exceed the value stated for the given length. The insertion loss performance is achieved by design.

13.3 Return loss

Balanced cords shall meet *RL* requirements specified in Table 80. The cords shall meet the electrical and mechanical requirements of IEC 61935-2.

Table 80 – Minimum return loss for balanced cords

Frequency MHz	**Return Loss** [a] MHz				
	Cord category				
	5	**6**	**6_A**	**7**	**7_A**
$1 \le f \le 25$	19,8 + 3 lg(*f*)	19,8 + 3 lg(*f*)	19,8 + 3 lg(*f*)	19,8 + 3 lg(*f*)	19,8 + 3 lg(*f*)
$25 < f \le 100$	38,0 – 10 lg(*f*)	38,0 – 10 lg(*f*)	38,0 – 10 lg(*f*)	38,0 – 10 lg(*f*)	38,0 – 10 lg(*f*)
$100 < f \le 250$	–	38,0 – 10 lg(*f*)	38,0 – 10 lg(*f*)	38,0 – 10 lg(*f*)	38,0 – 10 lg(*f*)
$250 < f \le 500$	–	–	14 – 15 lg(*f*/250)	38,0 – 10 lg(*f*)	38,0 – 10 lg(*f*)
$500 < f \le 600$	–	–	–	38,0 – 10 lg(*f*)	38,0 – 10 lg(*f*)
$600 < f \le 1\,000$	–	–	–	–	38,0 – 10 lg(*f*) [b]

[a] Return loss values at frequencies below 4 MHz are for information only.

[b] Calculated values below 10,0 dB revert to a 10,0 dB plateau.

Table 81 – Informative values of return loss for balanced cords at key frequencies

Frequency MHz	**Return Loss** dB				
	Cord category				
	5	**6**	**6_A**	**7**	**7_A**
1	19,8	19,8	19,8	19,8	19,8
100	18,0	18,0	18,0	18,0	18,0
250	–	14,0	14,0	14,0	14,0
500	–	–	9,5	11,0	11,0
600	–	–	–	10,2	10,2
1 000	–	–	–	–	10,0

13.4 NEXT

Balanced cords shall meet the requirement of Equation (9) when measured in accordance with IEC 61935-2.

$$NEXT_{\text{cord}} = -10\lg\left(10^{\frac{-NEXT_{\text{connectors}}}{10}} + 10^{\frac{-\left(NEXT_{\text{cable, L}} + 2\cdot IL_{\text{connector}}\right)}{10}}\right) - RFEXT \qquad (9)$$

where

$NEXT_{\text{cord}}$ is the *NEXT* of the cord;

$NEXT_{connectors}$ is the *NEXT* of both connectors in the cord, taking insertion loss into account;

$NEXT_{cable,\,L}$ is the *NEXT* of the cable adjusted for length;

$IL_{connector}$ is the insertion loss of one connector;

RFEXT is the reflected *FEXT*.

NOTE All variables are expressed in dB.

with

$$NEXT_{connectors} = -20\lg\left(10^{\frac{-NEXT_{local}}{20}} + 10^{\frac{-\left(NEXT_{remote} + 2\left(IL_{cable} + IL_{connector}\right)\right)}{20}}\right) \tag{10}$$

$$NEXT_{local} = NEXT_{remote} = NEXT_{connector} \tag{11}$$

$$IL_{cable} \approx \alpha_{cable,100\,m}\left(\frac{L}{100}\right) \tag{12}$$

where

$NEXT_{local}$ is the *NEXT* of the connector at the local end of the cord;

$NEXT_{remote}$ is the *NEXT* of the connector at the remote end of the cord;

IL_{cable} is the insertion loss of the cable;

$IL_{connector}$ is the insertion loss of the connector;

$NEXT_{connector}$ is the *NEXT* of each connector as specified in Table 51, with the exception of category 5 which is equal to 87 – 20 lg(f);

$\alpha_{cable,100\,m}$ is the insertion loss of 100 m of the cable used for the cord;

L is the length of the cable in the cord.

NOTE All variables are expressed in dB, except “*L*”, expressed in meters.

The length corrected near-end crosstalk of the cable of the cord is given by:

$$NEXT_{cable,L} = NEXT_{cable,\,100\,m} - 10\lg\left[\frac{1 - 10^{\frac{L}{100}\left(\frac{-\alpha_{cable,\,100\,m}}{5}\right)}}{1 - 10^{\left(\frac{-\alpha_{cable,\,100\,m}}{5}\right)}}\right] \tag{13}$$

where

$NEXT_{cable,\,100\,m}$ is the *NEXT* of a 100 m long cable section.

Calculations yielding *NEXT* limits in excess of 65 dB shall revert to a minimum requirement of 65 dB. Table 83 to Table 85 list informative values of *NEXT* at key frequencies for different length cords using the variable values outlined in Table 82.

Table 82 – Assumptions for cabling components used in the calculation of NEXT informative values

	Component category [a, b]				
Variable	**5**	**6**	**6_A**	**7**	**7_A**
α cable,100 m	$1{,}5\cdot(1{,}910\,8\sqrt{f} + 0{,}022\,2\,f + \frac{0{,}2}{\sqrt{f}})$	$1{,}5\cdot(1{,}82\sqrt{f} + 0{,}017\,f + \frac{0{,}25}{\sqrt{f}})$	$1{,}5\cdot(1{,}82\sqrt{f} + 0{,}009\,1\,f + \frac{0{,}25}{\sqrt{f}})$	$1{,}5\cdot(1{,}8\sqrt{f} + 0{,}01\,f + \frac{0{,}2}{\sqrt{f}})$	$1{,}5\cdot(1{,}8\sqrt{f} + 0{,}005\,f + \frac{0{,}25}{\sqrt{f}})$
NEXT cable, 100 m	$65{,}3 - 15\lg(f)$	$74{,}3 - 15\lg(f)$		$102{,}4 - 15\lg(f)$	$105{,}4 - 15\lg(f)$
IL connector	$0{,}04\sqrt{f}$	$0{,}02\sqrt{f}$			
NEXT connector	$87 - 20\lg(f)$	$94 - 20\lg(f)$	$94-20\lg(f)$, $f \le 250$ MHz $46{,}04 - 30\lg(f/250)$ $f > 250$ MHz	$102{,}4-15\lg(f)$	$116{,}3-20\lg(f)$ $f \le 600$ MHz $60{,}73 - 40\lg(f/600)$ $f > 600$ MHz
RFEXT	0	0,5			

[a] All equations apply from 1 MHz to the upper frequency of the category unless otherwise indicated.

[b] Values used for calculations may differ from the values specified in IEC 61156-5 an IEC 61156-6.

Table 83 – Informative values of NEXT for 2 m balanced cords at key frequencies

Frequency MHz	**NEXT** dB				
	Cord category				
	5	**6**	**6_A**	**7**	**7_A**
1	65,0	65,0	65,0	65,0	65,0
100	39,0	46,2	46,2	65,0	65,0
250	–	38,7	38,7	60,7	62,6
500	–	–	31,0	56,5	57,1
600	–	–	–	55,4	55,6
1 000	–	–	–	–	47,4

Table 84 – Informative values of NEXT for 5 m balanced cords at key frequencies

Frequency MHz	**NEXT** dB				
	Cord category				
	5	**6**	**6_A**	**7**	**7_A**
1	65,0	65,0	65,0	65,0	65,0
100	37,4	45,1	45,1	65,0	65,0
250	–	38,0	38,0	61,2	63,3
500	–	–	31,3	57,2	58,0
600	–	–	–	56,2	56,7
1 000	–	–	–	–	48,9

Table 85 – Informative values of NEXT for 10 m balanced cords at key frequencies

Frequency MHz	NEXT dB				
	Cord Category				
	5	**6**	**6$_A$**	**7**	**7$_A$**
1	65,0	65,0	65,0	65,0	65,0
100	36,4	44,2	44,2	65,0	65,0
250	–	37,6	37,6	61,9	64,1
500	–	–	31,7	58,0	59,1
600	–	–	–	57,0	57,8
1 000	–	–	–	–	50,2

Annex A
(normative)

Balanced permanent link and CP link performance

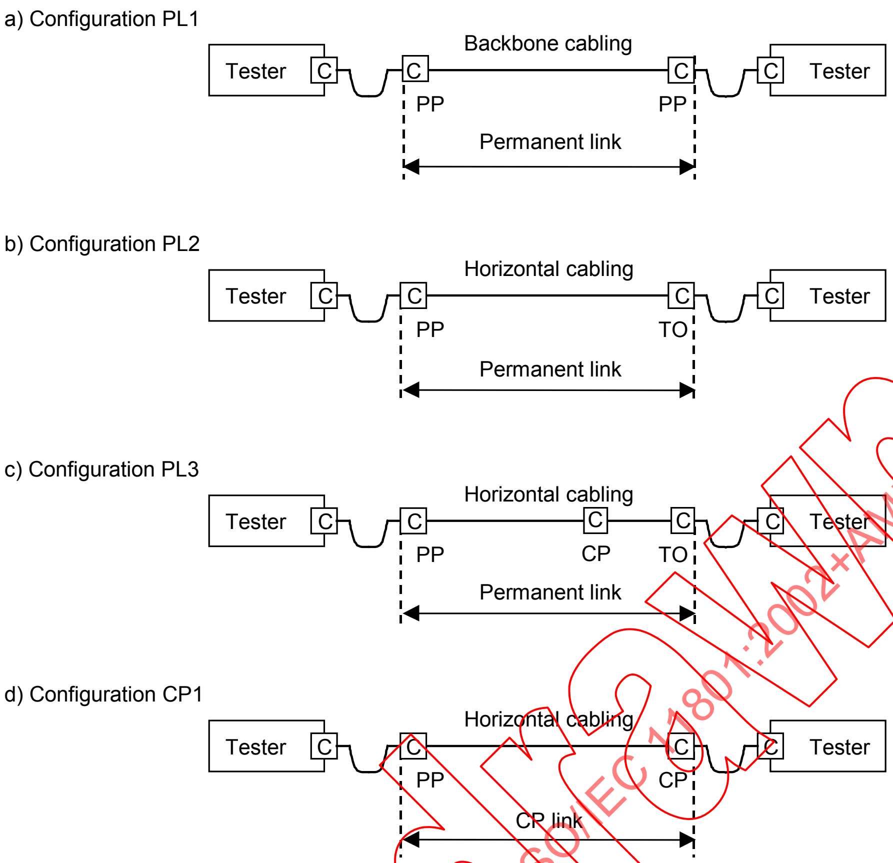
A.1 General

This annex contains performance requirements for balanced permanent links and CP links as shown in Figure A.1.

The cabling under test in configurations PL1, PL2 and PL3 is termed the permanent link. The configurations PL1 and PL2 comprise fixed cabling only. Configuration PL3 comprises fixed cabling and a CP cable between the CP and the TO. If the CP cable is changed, performance of this configuration will change. The cabling under test in configuration CP1 contains fixed cabling only and is termed the CP link. The difference between the CP link and the PL2 link is that the CP link is assumed to be extended, in the future, to a permanent link by the addition of cabling components. The difference between PL2 and PL3 specifications are related to the mathematical model length assumptions of Table 32, and the addition of cords to create a channel.

In all configurations the test reference plane of a permanent link or CP link is within the test cord. The test cord connector which mates with the termination point of the permanent link or CP link under test is part of the link under test.

Consideration should be given to calculating worst case performance at the worst case temperatures, when measuring performance at other temperatures.



PP = patch panel; C = connection; CP = consolidation point;
TO = telecommunications outlet;

Figure A.1 – Link options

A.2 Balanced cabling

A.2.1 General

The parameters specified in this annex apply to balanced permanent links and CP links with screened or unscreened cable elements, with or without an overall screen, unless explicitly stated otherwise. When required, permanent link and CP link measurements (including those required for permanent link and CP link calculations) shall be measured according to IEC 61935-1, unless otherwise specified in this annex.

The nominal impedance of balanced permanent links and CP links is 100 Ω. This impedance is achieved by suitable design, and an appropriate choice of cabling components (irrespective of their nominal impedance).

The requirements in this annex are given by limits computed, to one decimal place, using the equation for a defined frequency range. The limits for the propagation delay and delay skew are computed to three decimal places. Where relevant, in the informative tables for maximum implementation at key frequencies, the values of *L*, *Y* and *n* are: *L* = 90, *Y* = 1 and *n* = 3. Permanent link and CP link requirements for unbalanced attenuation and coupling attenuation are f.f.s.

A.2.2 Return loss

The *RL* of each pair of a permanent link or CP link shall meet the requirements derived by the equation in Table A.1.

The *RL* of each pair of a permanent link at key frequencies is given in Table A.2 for information only.

The *RL* requirements shall be met at both ends of the cabling.

Terminations of 100 Ω shall be connected to the cabling elements under test at the remote end of the link.

Table A.1 – Return loss for permanent link or CP link

Class	Frequency MHz	Minimum return loss [a] dB
C	$1 \le f \le 16$	15,0
D	$1 \le f \le 20$	19,0
	$20 < f \le 100$	32 – 10 lg(f)
E	$1 \le f \le 10$	21,0
	$10 < f \le 40$	26 – 5 lg(f)
	$40 < f \le 250$	34 – 10 lg(f)
E_A	$1 \le f \le 10$	21,0
	$10 < f \le 40$	26 – 5 lg(f)
	$40 < f \le 398,1$	34 – 10 lg(f)
	$398,1 < f \le 500$	8,0
F	$1 \le f \le 10$	21,0
	$10 < f \le 40$	26 – 5 lg(f)
	$40 < f \le 251,2$	34 – 10 lg(f)
	$251,2 < f \le 600$	10,0
F_A	$1 \le f \le 10$	21,0
	$10 < f \le 40$	26 – 5 lg(f)
	$40 < f \le 251,2$	34 – 10 lg(f)
	$251,2 < f \le 631$	10,0
	$631 < f \le 1\,000$	38 – 10 lg(f)

[a] *RL* values at frequencies where the insertion loss is below 3,0 dB are for information only.

Table A.2 – Informative return loss values for permanent link at key frequencies

Frequency MHz	Minimum return loss dB					
	Class C	Class D	Class E	Class E_A	Class F	Class F_A
1	15,0	19,0	21,0	21,0	21,0	21,0
16	15,0	19,0	20,0	20,0	20,0	20,0
100	–	12,0	14,0	14,0	14,0	14,0
250	–	–	10,0	10,0	10,0	10,0
500	–	–	–	8,0	10,0	10,0
600	–	–	–	–	10,0	10,0
1 000	–	–	–	–	–	8,0

A.2.3 Insertion loss/attenuation

The insertion loss of each pair of a permanent link or CP link shall meet the requirements derived by the equation in Table A.3.

A method of establishing conformant link performance is to demonstrate that the margin between the measured value and the channel limits of Table 4 are adequate to accommodate any additional cabling components used to create a channel.

The insertion loss of each pair of a permanent link, with maximum implementation, at key frequencies is given in Table A.4 for information only.

Table A.3 – Insertion loss for permanent link or CP link

Class	Frequency MHz	Maximum insertion loss [a] dB
A	f = 0,1	16,0
B	f = 0,1	5,5
	f = 1	5,8
C	$1 \leq f \leq 16$	$0{,}9 \times \left(3{,}23\sqrt{f}\right) + 3 \times 0{,}2$
D	$1 \leq f \leq 100$	$(L/100) \times \left(1{,}910\ 8\sqrt{f} + 0{,}022\ 2 \times f + 0{,}2/\sqrt{f}\right) + n \times 0{,}04 \times \sqrt{f}$
E	$1 \leq f \leq 250$	$(L/100) \times \left(1{,}82\sqrt{f} + 0{,}016\ 9 \times f + 0{,}25/\sqrt{f}\right) + n \times 0{,}02 \times \sqrt{f}$
E_A	$1 \leq f \leq 500$	$(L/100) \times \left(1{,}82\sqrt{f} + 0{,}009\ 1 \times f + 0{,}25/\sqrt{f}\right) + n \times 0{,}02 \times \sqrt{f}$
F	$1 \leq f \leq 600$	$(L/100) \times \left(1{,}8\sqrt{f} + 0{,}01 \times f + 0{,}2/\sqrt{f}\right) + n \times 0{,}02 \times \sqrt{f}$
F_A	$1 \leq f \leq 1\ 000$	$(L/100) \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + 0{,}25/\sqrt{f}\right) + n \times 0{,}02 \times \sqrt{f}$

NOTE

$L = L_{FC} + L_{CP}\ Y$

L_{FC} = length of fixed cable (m)

L_{CP} = length of CP cord (where present) (m)

Y = the ratio of CP cable insertion loss (dB/m) to fixed horizontal cable insertion loss (dB/m) (see 7.2.2.2)

n = 2 for configurations PL1, PL2 and CP1 (see Figure A.1, section a, b, and d)

n = 3 for configuration PL3 (see Figure A.1, section c)

[a] Insertion loss (IL) at frequencies that correspond to calculated values of less than 4,0 dB shall revert to a maximum requirement of 4,0 dB.

Table A.4 – Informative insertion loss values for permanent link with maximum implementation at key frequencies

Frequency MHz	Maximum insertion loss dB							
	Class A	Class B	Class C	Class D	Class E	Class E_A	Class F	Class F_A
0,1	16,0	5,5	–	–	–	–	–	–
1	–	5,8	4,0	4,0	4,0	4,0	4,0	4,0
16	–	–	12,2	7,7	7,1	7,0	6,9	6,8
100	–	–	–	20,4	18,5	17,8	17,7	17,3
250	–	–	–	–	30,7	28,9	28,8	27,7
500	–	–	–	–	–	42,1	42,1	39,8
600	–	–	–	–	–	–	46,6	43,9
1 000	–	–	–	–	–	–	–	57,6

A.2.4 NEXT

A.2.4.1 Pair-to-pair NEXT

The NEXT of each pair combination of a permanent link or CP link shall meet the requirements derived by the equation in Table A.5.

The *NEXT* of each pair combination of a permanent link, with maximum implementation, at key frequencies is given in Table A.6 for information only.

The *NEXT* requirements shall be met at both ends of the cabling.

Table A.5 – NEXT for permanent link or CP link

Class	Frequency MHz	Minimum NEXT [a, b, h] dB
A	$f = 0{,}1$	27,0
B	$0{,}1 \le f \le 1$	$25 - 5\lg(f)$
C	$1 \le f \le 16$	$40{,}1 - 15{,}8\lg(f)$
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{65{,}3-15\lg(f)}{-20}}+10^{\frac{83-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{74{,}3-15\lg(f)}{-20}}+10^{\frac{94-20\lg(f)}{-20}}\right)$
E_A [h]	$1 \le f \le 300$	$-20\lg\left(10^{\frac{74{,}3-15\lg(f)}{-20}}+10^{\frac{94-20\lg(f)}{-20}}\right)$
	$300 < f \le 500$	$87{,}46 - 21{,}57\lg(f)$ [c, d]
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{102{,}4-15\lg(f)}{-20}}+10^{\frac{102{,}4-15\lg(f)}{-20}}\right)$
F_A [g]	$1 \le f \le 600$	$106{,}1 - 18{,}5\lg(f)$
	$600 < f \le 1\,000$	$124{,}85 - 25{,}25\lg(f)$ [e, f]

[a] *NEXT* at frequencies that correspond to calculated values of greater than 65,0 dB shall revert to a minimum requirement of 65,0 dB.

[b] *NEXT* values at frequencies where the insertion loss (*IL*) is below 4,0 dB are for information only.

[c] For configuration PL3 (see Figure A.1, section c) this equation is $102{,}22 - 27{,}54\lg(f)$

[d] For configurations PL1, PL2, and CP1, whenever the class E_A permanent link insertion loss at 450 MHz is less than 12 dB, subtract the term $1{,}4((f - 450)/50)$ to the equation stated above for the range of 450 MHz to 500 MHz.

[e] For configuration PL3 (see Figure A.1, section c) this equation is $139{,}7 - 30{,}6\lg(f)$

[f] For configurations PL1, PL2, and CP1, whenever the class F_A permanent link insertion loss at 900 MHz is less than 17 dB, subtract the term $2{,}8((f - 900)/100)$ to the equation stated above for the range of 900 MHz to 1 000 MHz.

[g] When using connecting hardware with enhanced performance at the CP (see 10.2.4.3), the CP link limits do not represent appropriate minimum performance requirements, and therefore do not apply. In this case, the PL3 shall be tested for compliance instead.

[h] The terms in the equations are not intended to imply component performance.

Table A.6 – Informative NEXT values for permanent link with maximum implementation at key frequencies

Frequency MHz	Minimum NEXT dB							
	Class A	Class B	Class C	Class D	Class E	Class E_A	Class F	Class F_A
0,1	27,0	40,0	–	–	–	–	–	–
1	–	25,0	40,1	64,2	65,0	65,0	65,0	65,0
16	–	–	21,1	45,2	54,6	54,6	65,0	65,0
100	–	–	–	32,3	41,8	41,8	65,0	65,0
250	–	–	–	–	35,3	35,3	60,4	61,7
500	–	–	–	–	–	29,2 (27,9)[a]	55,9	56,1
600	–	–	–	–	–	–	54,7	54,7
1 000	–	–	–	–	–	–	–	49,1 (47,9)[a]

[a] Value applicable to configuration PL3 (see Figure A.1, section c).

A.2.4.2 Power sum NEXT (PS NEXT)

The PS *NEXT* requirements are applicable only to classes D, E, E_A, F and F_A.

The *PS NEXT* of each pair of a permanent link or CP link shall meet the requirements derived by the equation in Table A.7.

The *PS NEXT* of each pair of a permanent link, with maximum implementation, at key frequencies is given in Table A.8 for information only.

The *PS NEXT* requirements shall be met at both ends of the cabling.

$PS\ NEXT_k$ of pair k is computed as follows:

$$PS\ NEXT_k = -10\lg \sum_{i=1,\, i\neq k}^{n} 10^{\frac{-NEXT_{ik}}{10}} \qquad \text{(A.1)}$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

n is the total number of pairs;

$NEXT_{ik}$ is the near end crosstalk loss coupled from pair i into pair k.

Table A.7 – PS NEXT for permanent link or CP link

Class	**Frequency** MHz	**Minimum PS NEXT** [a, b, h] dB
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{62,3-15\lg(f)}{-20}}+10^{\frac{80-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}}+10^{\frac{90-20\lg(f)}{-20}}\right)$
E_A [h]	$1 \le f \le 300$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}}+10^{\frac{90-20\lg(f)}{-20}}\right)$
	$300 < f \le 500$	$87,56 - 22,67\lg(f)$ [c, d]
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{99,4-15\lg(f)}{-20}}+10^{\frac{99,4-15\lg(f)}{-20}}\right)$
F_A [g]	$1 \le f \le 600$	$103,1 - 18,5\lg(f)$
	$600 < f \le 1\,000$	$121,85 - 25,25\lg(f)$ [e, f]

[a] *PS NEXT* at frequencies that correspond to calculated values of greater than 62,0 dB shall revert to a minimum requirement of 62,0 dB.

[b] *PS NEXT* values at frequencies where the insertion loss *(IL)* is below 4,0 dB are for information only.

[c] For configuration PL3 (see Figure A.1, section c) this equation is $104,65 - 29,57\lg(f)$.

[d] For Configurations PL1, PL2, and CP1, whenever the class E_A permanent link insertion loss at 450 MHz is less than 12 dB, subtract the term $1,4((f - 450)/50)$ to the equation stated above for the range of 450 MHz to 500 MHz.

[e] For configuration PL3 (see Figure A.1, section c) this equation is $136,7 - 30,6\lg(f)$.

[f] For Configurations PL1, PL2, and CP1, whenever the class F_A permanent link insertion loss at 900 MHz is less than 17 dB, subtract the term $2,8((f - 900)/100)$ to the equation stated above for the range of 900 MHz to 1 000 MHz.

[g] When using connecting hardware with enhanced performance at the CP (see 10.2.4.3), the CP link limits do not represent appropriate minimum performance requirements, and therefore do not apply. In this case, the PL3 shall be tested for compliance instead.

[h] The terms in the equations are not intended to imply component performance.

Table A.8 – Informative PS NEXT values for permanent link with maximum implementation at key frequencies

Frequency MHz	Minimum PS NEXT dB				
	Class D	Class E	Class E_A	Class F	Class F_A
1	57,0	62,0	62,0	62,0	62,0
16	42,2	52,2	52,2	62,0	62,0
100	29,3	39,3	39,3	62,0	62,0
250	–	32,7	32,7	57,4	58,7
500	–	–	26,4 (24,8)[a]	52,9	53,1
600	–	–	–	51,7	51,7
1 000	–	–	–	–	46,1 (44,9)[a]

[a] Value applicable to configuration PL3 (see Figure A.1, section c).

A.2.5 Attenuation to crosstalk ratio at the near-end (ACR-N)

A.2.5.1 General

The *ACR-N* requirements are applicable only to Classes D, E, E_A, F, and F_A.

A.2.5.2 Pair-to-pair ACR-N

Pair-to-pair *ACR-N* is the difference between the pair-to-pair *NEXT* and the insertion loss of the cabling in dB.

The *ACR-N* of each pair combination of a permanent link or CP link shall meet the difference of the *NEXT* requirement of Table A.5 and the insertion loss requirement of Table A.3 of the respective class.

The *ACR-N* of each pair combination of a permanent link, with maximum implementation, at key frequencies is given in Table A.9 for information only.

The *ACR-N* requirements shall be met where the *NEXT* requirements apply, and at both ends of the cabling.

$ACR\text{-}N_{ik}$ of pairs *i* and *k* is computed as follows:

$$ACR\text{-}N_{ik} = NEXT_{ik} - IL_k \qquad \text{(A.2)}$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

$NEXT_{ik}$ is the near end crosstalk loss coupled from pair i into pair k;

IL_k is the insertion loss of pair k.

Table A.9 – Informative ACR-N values for permanent link with maximum implementation at key frequencies

Frequency MHz	Minimum ACR-N dB				
	Class D	**Class E**	**Class E_A**	**Class F**	**Class F_A**
1	60,2	61,0	61,0	61,0	61,0
16	37,5	47,5	47,6	58,1	58,2
100	11,9	23,3	24,0	47,3	47,7
250	–	4,7	6,4	31,6	34,0
500	–	–	−12,9 (-14,2)[a]	13,8	16,4
600	–	–	–	8,1	10,8
1 000	–	–	–	–	−8,5 (-9,7)[a]

[a] Value applicable to Configuration PL3 (see Figure A.1, section c).

A.2.5.3 Power sum ACR-N (PS ACR-N)

The *PS ACR-N* of each pair of a permanent link or CP link shall meet the difference of the *PS NEXT* requirement of Table A.7 and the insertion loss requirement of Table A.3 of the respective class.

The *PS ACR-N* of each pair of a permanent link, with maximum implementation, at key frequencies is given in Table A.10 for information only.

The *PS ACR-N* requirements shall be met where the *PS NEXT* requirements apply, and at both ends of the cabling.

$PS\ ACR\text{-}N_k$ of pair k is computed as follows:

$$PS\ ACR\text{-}N_k = PS\ NEXT_k - IL_k \qquad \text{(A.3)}$$

where

k is the number of the disturbed pair;

$PS\ NEXT_k$ is the power sum near end crosstalk loss of pair k;

IL_k is the insertion loss of pair k.

Table A.10 – Informative PS ACR-N values for permanent link with maximum implementation at key frequencies

Frequency MHz	Minimum PS ACR-N dB				
	Class D	**Class E**	**Class E_A**	**Class F**	**Class F_A**
1	53,0	58,0	58,0	58,0	58,0
16	34,5	45,1	45,2	55,1	55,2
100	8,9	20,8	21,5	44,3	44,7
250	–	2,0	3,8	28,6	31,0
500	–	–	−15,7 (−16,3)[a]	10,8	13,4
600	–	–	–	5,1	7,8
1 000	–	–	–	–	−11,5 (−12,7)[a]

[a] Value applicable to Configuration PL3 (see Figure A.1, section c).

A.2.6 Attenuation to crosstalk ratio at the far-end (ACR-F)

A.2.6.1 General

The *ACR-F* requirements are applicable only to Classes D, E, E_A, F, and F_A.

A.2.6.2 Pair-to-pair ACR-F

The ACR-F of each pair combination of a permanent link or CP link shall meet the requirements derived by the Equation (A.4).

The *ACR-F* of each pair combination of a permanent link, with maximum implementation, at key frequencies is given in Table A.12 for information only.

$ACR\text{-}F_{ik}$ of pairs *i* and *k* is computed as follows:

$$ACR\text{-}F_{ik} = FEXT_{ik} - IL_k \tag{A.4}$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

$FEXT_{ik}$ is the far end crosstalk loss coupled from pair i into pair k;

IL_k is the insertion loss of pair k.

NOTE The difference of input-to-output *FEXT* and the insertion loss of the disturbed pair is relevant to the signal-to-noise consideration. The results computed to the formal definition above cover all possible combinations of insertion loss of pairs and corresponding input-to-output *FEXT*.

Table A.11 – ACR-F for permanent link or CP link

Class	Frequency MHz	Minimum ACR-F [a, b, c] dB
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{63,8-20\lg(f)}{-20}}+n\times 10^{\frac{75,1-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{67,8-20\lg(f)}{-20}}+n\times 10^{\frac{83,1-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{67,8-20\lg(f)}{-20}}+n\times 10^{\frac{83,1-20\lg(f)}{-20}}\right)$
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{94-20\lg(f)}{-20}}+n\times 10^{\frac{90-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{95,3-20\lg(f)}{-20}}+n\times 10^{\frac{103,9-20\lg(f)}{-20}}\right)$

NOTE n = 2 for configurations PL1, PL2 and CP1 (see Figure A.1, sections a, b, and d)
n = 3 for configuration PL3 (see Figure A.1, sections c).

[a] *ACR-F* at frequencies that correspond to measured FEXT values of greater than 70,0 dB are for information only.

[b] *ACR-F* at frequencies that correspond to calculated values of greater than 65,0 dB shall revert to a minimum requirement of 65,0 dB.

[c] The terms in the equations are not intended to imply component performance.

Table A.12 – Informative ACR-F values for permanent link with maximum implementation at key frequencies

Frequency MHz	**Minimum ACR-F** dB				
	Class D	**Class E**	**Class E_A**	**Class F**	**Class F_A**
1	58,6	64,2	64,2	65,0	65,0
16	34,5	40,1	40,1	59,3	64,7
100	18,6	24,2	24,2	46,0	48,8
250	–	16,2	16,2	39,2	40,8
500	–	–	10,2	34,0	34,8
600	–	–	–	32,6	33,2
1 000	–	–	–	–	28,8

A.2.6.3 Power sum ACR-F (PS ACR-F)

The *PS ACR-F* of each pair of a permanent link or CP link shall meet the requirements derived by the equations in Table A.13.

The *PS ACR-F* of each pair of a permanent link, with maximum implementation, at key frequencies is given in Table A.14 for information only.

PS ACR-F$_k$ of pair *k* is computed as follows:

$$PS\ ACR-F_k = (-10\lg \sum_{i=1, i\neq k}^{n} 10^{\frac{-FEXT_{ik}}{10}}) - IL_k \qquad \text{(A.5)}$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

n is the total number of pairs;

$FEXT_{ik}$ is the far end crosstalk loss coupled from pair i into pair k;

IL_k is the insertion loss of pair k.

Table A.13 – PS ACR-F for permanent link or CP link

Class	Frequency MHz	Minimum PS ACR-F [a, b, c] dB
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{60{,}8-20\lg(f)}{-20}} + n \times 10^{\frac{72{,}1-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{64{,}8-20\lg(f)}{-20}} + n \times 10^{\frac{80{,}1-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{64{,}8-20\lg(f)}{-20}} + n \times 10^{\frac{80{,}1-20\lg(f)}{-20}}\right)$
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{91-20\lg(f)}{-20}} + n \times 10^{\frac{87-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{92{,}3-20\lg(f)}{-20}} + n \times 10^{\frac{100{,}9-20\lg(f)}{-20}}\right)$

NOTE n = 2 for configurations PL1, PL2 and CP1 (see Figure A.1, sections a, b, and d)
n = 3 for configuration PL3 (see Figure A.1, section c)

[a] *PS ACR-F* at frequencies that correspond to measured *PS FEXT* values of greater than 70,0 dB are for information only.

[b] *PS ACR-F* at frequencies that correspond to calculated values of greater than 62,0 dB shall revert to a minimum requirement of 62,0 dB.

[c] The terms in the equations are not intended to imply component performance.

Table A.14 – Informative PS ACR-F values for permanent link with maximum implementation at key frequencies

Frequency MHz	Minimum PS ACR-F dB				
	Class D	Class E	Class E_A	Class F	Class F_A
1	55,6	61,2	61,2	62,0	62,0
16	31,5	37,1	37,1	56,3	61,7
100	15,6	21,2	21,2	43,0	45,8
250	–	13,2	13,2	36,2	37,8
500	–	–	7,2	31,0	31,8
600	–	–	–	29,6	30,2
1 000	–	–	–	–	25,8

A.2.7 Direct current (d.c.) loop resistance

The d.c. loop resistance of each pair of a permanent link or CP link shall meet the requirements derived by the equation in Table A.15.

A method of establishing conformant link performance is to demonstrate that the margin between the measured value and the channel limits of Table 16 are adequate to accommodate any additional cabling components used to create a channel. This is fulfilled if the insertion loss requirement and the delay skew requirement for the permanent link or CP link are met and test verification of a d.c. connection for each cabling conductor have been performed.

The d.c. loop resistance of each pair of a permanent link with maximum implementation length is given in Table A.16.

Table A.15 – Direct current (d.c.) loop resistance for permanent link or CP link

Class	Maximum d.c. loop resistance Ω
A	530
B	140
C	34
D	$(L/100) \times 22 + n \times 0{,}4$
E	$(L/100) \times 22 + n \times 0{,}4$
E_A	$(L/100) \times 22 + n \times 0{,}4$
F	$(L/100) \times 22 + n \times 0{,}4$
F_A	$(L/100) \times 22 + n \times 0{,}4$

where

L $L_{FC} + L_{CP} \times Y$

L_{FC} length of fixed cable (m)

L_{CP} length of CP cord (where present) (m)

Y the ratio of CP cable insertion loss (dB/m) to fixed horizontal cable insertion loss (dB/m) (see 7.2.2.2)

n 2 for Configurations PL1, PL2 and CP1 (see Figure A.1, sections a, b, and d)

n 3 for Configuration PL3 (see Figure A.1, section c)

Table A.16 – Informative d.c. loop resistance for permanent link with maximum implementation

Maximum d.c. loop resistance Ω							
Class A	Class B	Class C	Class D	Class E	Class E_A	Class F	Class F_A
530	140	34	21	21	21	21	21

A.2.8 Direct current (d.c.) resistance unbalance

The d.c. resistance unbalance between the two conductors within each pair of a permanent link or CP link shall not exceed the greater of 3 % or 0,150 Ω for all Classes. This shall be achieved by design.

A.2.9 Propagation delay

The propagation delay of each pair of a permanent link or CP link shall meet the requirements derived by the equations in Table A.17.

A method of establishing conformant link performance is to demonstrate that the margin between the measured value and the channel limits of Table 18 are adequate to accommodate any additional cabling components used to create a channel. This is fulfilled if the insertion loss requirement and the delay skew requirement for the permanent link or CP link are met.

The propagation delay of each pair of a permanent link, with maximum implementation, at key frequencies is given in Table A.18 for information only.

Table A.17 – Propagation delay for permanent link or CP link

Class	Frequency MHz	Maximum propagation delay µs
A	f = 0,1	19,400
B	0,1 ≤ f ≤ 1	4,400
C	1 ≤ f ≤ 16	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+n\times0{,}002\,5$
D	1 ≤ f ≤ 100	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+n\times0{,}002\,5$
E	1 ≤ f ≤ 250	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+n\times0{,}002\,5$
E_A	1 ≤ f ≤ 500	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+n\times0{,}002\,5$
F	1 ≤ f ≤ 600	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+n\times0{,}002\,5$
F_A	1 ≤ f ≤ 1 000	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+n\times0{,}002\,5$

where

L $L_{FC} + L_{CP}$

L_{FC} length of fixed cable (m)

L_{CP} length of CP cord (where present) (m)

n 2 for configurations PL1, PL2 and CP1 (see Figure A.1, sections a, b, and d)

n 3 for configuration PL3 (see Figure A.1, section c)

Table A.18 – Informative propagation delay values for permanent link with maximum implementation at key frequencies

Frequency MHz	Maximum propagation delay µs							
	Class A	Class B	Class C	Class D	Class E	Class E_A	Class F	Class F_A
0,1	19,400	4,400	–	–	–	–	–	–
1	–	4,400	0,521	0,521	0,521	0,521	0,521	0,521
16	–	–	0,496	0,496	0,496	0,496	0,496	0,496
100	–	–	–	0,491	0,491	0,491	0,491	0,491
250	–	–	–	–	0,490	0,490	0,490	0,490
500	–	–	–	–	–	0,490	0,490	0,490
600	–	–	–	–	–	–	0,489	0,489
1 000	–	–	–	–	–	–	–	0,489

A.2.10 Delay skew

The delay skew between all pairs of a permanent link or CP link shall meet the requirements derived by the equations in Table A.19.

A method of establishing a conformant link performance is to demonstrate that the margin between the measured value and the channel limits of Table 20 are adequate to accommodate any additional cabling components used to create a channel. This is fulfilled if the insertion loss requirement and the propagation delay requirement for the permanent link or CP link are met.

The delay skew between all pairs of a permanent link, with maximum implementation, at key frequencies is given in Table A.20 for information only.

Table A.19 – Delay skew for permanent link or CP link

Class	Frequency MHz	Maximum delay skew µs
A	f = 0,1	N/A
B	0,1 ≤ f ≤ 1	N/A
C	1 ≤ f ≤ 16	$(L/100) \times 0{,}045 + n \times 0{,}001\,25$
D	1 ≤ f ≤ 100	$(L/100) \times 0{,}045 + n \times 0{,}001\,25$
E	1 ≤ f ≤ 250	$(L/100) \times 0{,}045 + n \times 0{,}001\,25$
E_A	1 ≤ f ≤ 500	$(L/100) \times 0{,}045 + n \times 0{,}001\,25$
F	1 ≤ f ≤ 600	$(L/100) \times 0{,}025 + n \times 0{,}001\,25$
F_A	1 ≤ f ≤ 1 000	$(L/100) \times 0{,}025 + n \times 0{,}001\,25$

where

L L_{FC} + L_{CP}

L_{FC} length of fixed cable (m)

L_{CP} length of CP cord (where present) (m)

n 2 for configurations PL1, PL2 and CP1 (see Figure A.1, sections a, b, and d)

n 3 for configuration PL3 (see Figure A.1, section c)

Table A.20 – Informative delay skew for permanent link with maximum implementation

Class	Frequency MHz	Maximum delay skew µs
A	f = 0,1	N/A
B	0,1 ≤ f ≤ 1	N/A
C	1 ≤ f ≤ 16	0,044 [a]
D	1 ≤ f ≤ 100	0,044 [a]
E	1 ≤ f ≤ 250	0,044 [a]
E_A	1 ≤ f ≤ 500	0,044 [a]
F	1 ≤ f ≤ 600	0,026 [b]
F_A	1 ≤ f ≤ 1 000	0,026 [b]

[a] This is the result of the calculation 0,9 × 0,045+3 × 0,001 25.

[b] This is the result of the calculation 0,9 × 0,025+3 × 0,001 25.

A.2.11 Alien crosstalk

A.2.11.1 General

The following alien crosstalk requirements are applicable to Classes E_A and F_A only. Alien crosstalk of Class F is considered to be as good as the alien crosstalk performance specified for Class E_A. For information on alien crosstalk performance of Class E cabling, see ISO/IEC TR 24750.

If the coupling attenuation of Class E_A or F permanent links or CP links is at least 10 dB better than the corresponding channel coupling attenuation requirements (see Clause 6), and Class F_A permanent links or CP links are at least 25 dB better than the corresponding channel coupling attenuation requirements (see Clause 6), then the requirements of A.2.11 are met by design.

A.2.11.2 Power sum alien NEXT (PS ANEXT)

The *PS ANEXT* of each pair of a permanent link or CP link shall meet the requirements derived by the equations in Table A.21.

The *PS ANEXT* requirements shall be met at both ends of the cabling.

$PS\ ANEXT_k$ of pair k is computed as follows:

$$PS\ ANEXT_k = -10\lg\left[\sum_{l=1}^{N}\sum_{i=1}^{n}10^{\frac{-ANEXT_{l,i,k}}{10}}\right] \qquad \text{(A.7)}$$

where

k is the number of the disturbed pair in the disturbed link;

i is the number of the disturbing pair in a disturbing link l;

l is the number of the disturbing link;

N is the total number of disturbing links;

n is the number of disturbing pairs in disturbing link l;

$ANEXT_{l,i,k}$ is the alien near end crosstalk loss coupled from pair i of disturbing link l to the pair k of the disturbed link.

Table A.21 – PS ANEXT for permanent link or CP link

Class	Frequency MHz	Minimum PS ANEXT [a] dB
E_A [b]	$1 \le f < 100$	80 – 10lg (f)
	$100 \le f \le 500$	90 – 15lg (f)
F_A	$1 \le f < 100$	95 – 10lg (f)
	$100 \le f \le 1\,000$	105 – 15lg (f)

[a] *PS ANEXT* at frequencies that correspond to calculated values of greater than 67,0 dB shall revert to a minimum requirement of 67,0 dB.

[b] If the average insertion loss of all disturbed pairs at 100 MHz, $IL_{100\text{MHz,avg}}$ is less than 7 dB, then subtract the following for $f \ge 100$ MHz:

$$\text{minimum}\left\{7 \times \frac{f-100}{400} \times \frac{7 - IL_{100\text{MHz},\text{avg}}}{IL_{100\text{MHz},\text{avg}}},\ 6 \times \frac{f-100}{400}\right\}$$

where

f is the frequency in MHz;

$$IL_{100\text{MHz},\text{avg}} = \frac{1}{4}\sum_{i=1}^{4} IL_{100\text{MHz},\,i};$$

$IL_{100\text{MHz},\,i}$ is the insertion loss of a pair i at 100 MHz.

Table A.22 – Informative PS ANEXT values for permanent link at key frequencies

Frequency MHz	Minimum PS ANEXT dB	
	Class E_A	Class F_A
1	67,0	67,0
100	60,0	67,0
250	54,0	67,0
500	49,5	64,5
1 000	–	60,0

A.2.11.3 PS $ANEXT_{avg}$

The $PS\ ANEXT_{avg}$ of each permanent link or CP link shall meet the requirements derived by the equations in Table A.23.

The $PS\ ANEXT_{avg}$ requirements shall be met at both ends of the cabling.

$PS\ ANEXT_{avg}$ is computed as follows:

$$PS\ ANEXT_{avg} = \frac{1}{n}\left[\sum_{k=1}^{n} PS\ ANEXT_k\right] \qquad (A.8)$$

where

k is the number of the disturbed pair in the disturbed link;

n is the number of pairs in the disturbed link.

Table A.23 – PS ANEXT$_{avg}$ for permanent link or CP link

Class	**Frequency** MHz	**Minimum PS ANEXT$_{avg}$** [a, b, c] dB
E_A	$1 \le f < 100$	$82{,}25 - 10 \lg (f)$
	$100 \le f \le 500$	$92{,}25 - 15 \lg (f)$

[a] PS $ANEXT_{avg}$ at frequencies that correspond to calculated values of greater than 67,0 dB shall revert to a minimum requirement of 67,0 dB.

[b] If the average insertion loss of all disturbed pairs at 100 MHz, $IL_{100MHz,avg}$, is less than 7 dB, then subtract the following for $f \ge 100$ MHz:

$$\text{minimum}\left\{7 \times \frac{f - 100}{400} \times \frac{7 - IL_{100MHz,avg}}{IL_{100MHz,avg}},\ 6 \times \frac{f - 100}{400}\right\}$$

where

f is the frequency in MHz;

$$IL_{100MHz,avg} = \frac{1}{4}\sum_{i=1}^{4} IL_{100MHz,i};$$

$IL_{100MHz,i}$ is the insertion loss of a pair i at 100 MHz.

[c] *PS ANEXT$_{avg}$* for Class E_A links is met if the Class F_A *PS ANEXT* specification limits in Table A.21 are met.

Table A.24 – Informative PS ANEXT$_{avg}$ values for permanent link at key frequencies

Frequency MHz	**Minimum Class E_A PS ANEXT$_{avg}$** dB
1	67,0
100	62,3
250	56,3
500	51,8

A.2.11.4 PS AFEXT for Class E_A permanent links or CP links

The *PS AFEXT* for Class E_A is computed as follows:

$AFEXT_{norm}$ is computed from Equations A.9 to A.12 as follows

If

$$IL_k - IL_{l,i} > 0 \qquad \text{(A.9)}$$

then

$$AFEXT_{\mathrm{norm}\,l,i,k} = AFEXT_{l,i,k} - IL_{l,i} + IL_k - 10\lg\left(\frac{IL_k}{IL_{l,i}}\right) \qquad \text{(A.10)}$$

The measured pair-to-pair alien *FEXT* values of a pair *k* in a disturbed link from the disturbing link *l* are normalized by the difference of the insertion losses of disturbing and disturbed link.

If

$$IL_k - IL_{l,i} \le 0 \qquad \text{(A.11)}$$

then

$$AFEXT_{\mathrm{norm}\,l,i,k} = AFEXT_{l,i,k} \qquad \text{(A.12)}$$

where

k	is the number of the disturbed pair in the disturbed link;
i	is the number of the disturbing pair in a disturbing link l;
l	is the number of the disturbing link;
$AFEXT_{l,i,k}$	is the alien far end crosstalk loss coupled from pairs i into pair k;
IL_k	is the measured insertion loss of pair k in the disturbed link;
$IL_{l,i}$	is the measured insertion loss of pair i of disturbing link l.

The *PS AFEXT* is determined according to Equation (A.13).

$$PS\,AFEXT_k = -10\lg\left(\sum_{l=1}^{N}\sum_{i=1}^{n} 10^{\frac{-\left(AFEXT_{\mathrm{norm}\,l,i,k}\right)}{10}}\right) \qquad \text{(A.13)}$$

where

N is the total number of disturbing links;

n is the number of disturbing pairs in disturbing link l;

k is the number of the disturbed pair in the disturbed link;

i is the number of the disturbing pair in a disturbing link l;

l is the number of the disturbing link.

A.2.11.5 PS AFEXT for Class F_A permanent links or CP links

The *PS AFEXT* is determined according to Equation A.14.

$$PS\,AFEXT_k = -10\lg\left(\sum_{l=1}^{N}\sum_{i=1}^{n} 10^{\frac{-\left(AFEXT_{l,i,k}\right)}{10}}\right) \qquad \text{(A.14)}$$

where

N is the total number of disturbing links;

n is the number of disturbing pairs in disturbing link l;

k is the number of the disturbed pair in the disturbed link;

i is the number of the disturbing pair in a disturbing link l;

l is the number of the disturbing link.

A.2.11.6 Power sum alien ACR-F (PS AACR-F) for Class E_A and Class F_A permanent links or CP links

The *PS AACR-F* of each pair of a permanent link or CP link shall meet the requirements derived by the equation in Table A.25.

The *PS AACR-F* shall be met at both ends of the cabling.

The *PS AACR-F* is computed based on *AFEXT* and insertion losses of disturbing and disturbed links.

The *PS AACR-F*$_k$ of disturbed pair k is determined according to Equation (A.15).

$$PS\,AACR\text{-}F_k = PS\,AFEXT_k - IL_k \qquad \text{(A.15)}$$

Table A.25 – PS AACR-F for permanent link or CP link

Class	Frequency MHz	Minimum PS AACR-F [a, b] dB
E_A	$1 \le f \le 500$	$77 - 20\lg(f)$
F_A	$1 \le f \le 1\,000$	$92 - 20\lg(f)$

[a] *PS AACR–F* at frequencies that correspond to calculated PS AFEXT values of greater than 67,0 dB or 102 − 15 lg(f) dB shall be for information only.

[b] *PS AACR-F* at frequencies that correspond to calculated values of greater than 67,0 dB shall revert to a minimum requirement of 67,0 dB.

Table A.26– Informative PS AACR-F values for permanent link at key frequencies

Frequency MHz	Minimum PS AACR-F dB	
	Class E_A	Class F_A
1	67,0	67,0
100	37,0	52,0
250	29,0	44,0
500	23,0	38,0
1 000	–	32,0

A.2.11.7 PS AACR-F_{avg} for Class E_A and Class F_A permanent links or CP links

The *PS AACR-F_{avg}* of each permanent link or CP link shall meet the requirements derived by the equations in Table A.27.

The *PS AACR-F_{avg}* requirements shall be met at both ends of the cabling.

PS AACR-F_{avg} is computed as follows:

$$PS\ AACR\text{-}F_{avg} = \frac{1}{n}\left[\sum_{k=1}^{n} PS\ AACR\text{-}F_k\right] \quad (A.16)$$

where

k is the number of the disturbed pair in the disturbed link;

n is the number of pairs in the disturbed link.

Table A.27 – PS AACR-F_{avg} for permanent link or CP link

Class	Frequency MHz	Minimum PS AACR-F_{avg} [a, b, c] dB
E_A	$1 \leq f \leq 500$	$81 - 20\lg(f)$

[a] *PS AACR–F_{avg}* at frequencies that correspond to calculated *PS AFEXT$_{avg}$* values of greater than 67,0 dB or 102 − 15 lg(f) dB shall be for information only.

[b] *PS AACR–F_{avg}* at frequencies that correspond to calculated values of greater than 67,0 dB shall revert to a minimum requirement of 67,0 dB.

[c] *PS AACR–F_{avg}* for Class F_A links is met if the Class F_A *PS AACR-F* specification limits in Table 26 are met.

Table A.28– Informative PS AACR-F_{avg} values for permanent link at key frequencies

Frequency MHz	**Minimum Class E_A PS AACR-F_{avg}** dB
1	67,0
100	41,0
250	33,0
500	27,0

Annex B
(normative)

Test procedures

B.1 General

This annex contains requirements and recommendations for testing of channels, permanent links and CP links in order to determine their conformance to this International Standard.

B.2 Channel and link performance testing

B.2.1 General

- Performance testing can be undertaken eitherin a laboratory, where channels, permanent links or CP links contain specific cabling components in a specific implementation, or

- in the field, after installation, using test equipment.

This testing is independent from any requirements for acceptance testing contained within an installation specification, as in ISO/IEC 14763-2.

There are two kinds of conformance testing:

a) reference conformance testing;

This testing is performed on a sample of installed cabling in a laboratory where an assessment against the conformance criteria of Clause 4 is required. The assessment documentation will include details of the number of channels or links tested, test evaluation criteria, supplier's declarations and certification, laboratory accreditation and calibration certification, etc.

This testing can also be used for

- the comparison of measurements performed with laboratory and field test instruments,
- assessing cabling models in a laboratory environment,
- assessing parameters that cannot be tested in an installation.

b) installation conformance testing;

This testing is performed on a complete installation of cabling in the field where an assessment against the conformance criteria of Clause 4 is required.

Conformance testing of both kinds may be performed by independent or third party organisations in order to give greater guarantees of compliance. Reference testing is also known as type testing.

B.2.2 Installation conformance testing of balanced cabling channels, permanent links and CP links

Testing to determine conformance with the requirements of Clause 6 is optional. Testing should be performed in the following cases:

c) channels, permanent links, or CP links with lengths exceeding, or having more components than, those specified in reference implementations of Clause 7;

d) permanent links or CP links using components whose transmission performance is lower than those described in Clauses 9 and 10;

e) channels using components whose transmission performance is lower than those described in Clauses 9, 10 and 13;

f) channels created by adding more than one cord to either end of a link meeting the requirements of Clause 6 and Annex A;

g) evaluation of cabling to determine its capacity to support a certain group of applications;

h) confirmation of performance of cabling designed in accordance with Clause 7, using Clauses 9, 10 and 13.

i) Channels containing cable segments with lengths that are outside the assumed ranges in Table 32.

The test procedures for balanced cabling channels, permanent links and CP links are specified in IEC 61935-1.

B.2.3 Installation conformance testing of optical fibre cabling channels

Testing to determine conformance with the requirements of Clause 8 is optional. Testing should be performed in the following cases:

a) evaluation of cabling to determine its ability to support a certain group of applications;

b) confirmation of performance of cabling designed in accordance with Clauses 8, 9 and 10.

The test procedures for optical fibre cabling channels and permanent links are specified in ISO/IEC 14763-3.

B.3 Overview of test regimes

A test regime for each of the two kinds of conformance testing (see B.2.1) is defined for each transmission parameter. The test regime for balanced cabling reference conformance and installation conformance testing is shown in Table B.1. The test regime for optical fibre cabling reference conformance and installation conformance testing is shown in Table B.2.

Table B.1 – Test regime for reference conformance and installation conformance – Balanced cabling

Transmission parameter [b]	Reference conformance testing	Installation conformance testing
Return loss	N	N
Insertion loss	N	N
Pair-to-pair NEXT	N	N
PS NEXT	C	C
Pair-to-pair ACR-N	C	C
PS ACR-N	C	C
Pair-to-pair ACR-F	N	N
PS ACR-F	C	C
Direct current (d.c.) loop resistance	N	N
Direct current (d.c.) resistance unbalance	N	I
Propagation delay	N	N
Delay skew	N	N
Unbalance attenuation, near-end (TCL)	N	I
Unbalance attenuation, far-end (ELTCTL)	N	I
Coupling attenuation	N	I
PS ANEXT	N	N_S
PS $ANEXT_{avg}$	C	C
PS AACR-F	N	N_S
PS $AACR\text{-}F_{avg}$	C	C
Wire-map	N	N
Continuity: • signal conductors; • screen conductors (if present); • short circuits; • open circuits.	N	N
Length [a]	I	I

where

C is the calculated value;

I is the informative (optional) testing;

N is the normative (100 %) testing, if not met by design;

N_S is the normative (sampled) testing, if not met by design. The sample size to be tested should be in accordance with ISO/IEC 14763-2.

NOTE The term "met by design" refers to a requirement which may be met by the selection of appropriate materials and installation techniques.

[a] Length is not a pass/fail criterion.

[b] Only those parameters specified for each Class of cabling need to be tested, as required in Amendment 1:2008 and Annex A.

Table B.2 – Test regime for reference conformance and installation conformance – Optical fibre cabling

Transmission parameter	Reference conformance testing	Installation conformance testing
Attenuation	N	N
Propagation delay [a]	I	I
Polarity	N	N
Length	I	I
Connector return loss [b]	N	N
where I = Informative (optional) testing. N = Normative (100 %) testing.		
[a] Propagation delay is not a pass/fail criterion. [b] This is a requirement for connecting hardware return loss (see Clause 10).		

Annex C
(normative)

Mechanical and environmental performance testing of connecting hardware for balanced cabling

C.1 Overview

The mechanical and environmental performance of connecting hardware is vital to the cabling system. Changes in contact resistance because of operational and environmental stress can negatively affect the transmission characteristics of the cabling system. Product acceptance testing is accomplished by subjecting the product to a number of mechanical and environmental conditions and measuring any resistance deviations at prescribed intervals and after completion of each conditioning sequence. In addition, the product shall not show evidence of degradation with respect to the ease of mechanical termination, safety or other functional attributes during or after environmental conditioning.

Connecting hardware often contains a combination of solderless connections and a separable contact interface (free connector/fixed connector interface). All connections shall be tested. Where a combination of connections and/or separable contact interfaces are tested together, care should be taken to ensure the use of the most stringent test schedule as the test schedules vary by type of connection.

This annex provides mechanical connection performance requirements for connections that are not covered by a specific IEC connector standard. This annex is intended to be replaced by reference to international standards, as soon as they become available.

NOTE Connection interfaces that conform to the mechanical and environmental performance requirements of IEC 60603-7 (unscreened) or IEC 60603-7-1 (screened) comply with this annex as these standards specify appropriate tests. Connection interfaces that are covered by international standards other than the IEC 60603-7 series must comply with at least the equivalent mechanical and environmental performance requirements specified in this annex.

C.2 Solderless connections

To ensure reliable solderless terminations of balanced cable with insulated conductors, and to ensure reliable solderless connections between component parts within connecting hardware, solderless connections shall meet the requirements of the applicable standards specified in Table C.1.

Table C.1 – Standards for solderless connections

Connection type	Standard
Crimped connection	IEC 60352-2
Accessible IDC	IEC 60352-3
Non-accessible IDC	IEC 60352-4
Press-in connection	IEC 60352-5
IPC	IEC 60352-6
Spring clamp connection	IEC 60352-7
Compression mount	IEC 60352-8

The default criteria and conditions in the relevant standards in Table C.1 apply, except as specified in the remainder of this clause.

The maximum initial contact resistance for an insulation displacement connection shall be 2,5 mΩ and the maximum change in contact resistance during and after conditioning shall be 5 mΩ from the initial value.

The following test conditions are specified, as detailed by the type test requirements of the IEC 60352 series of standards.

- Vibration test severity: 10 Hz to 500 Hz.
- Low temperature (LCT): –40 °C.
- Electrical load and temperature, test current: 1 A d.c.

C.3 Free and fixed connectors (modular plugs and jacks)

Fixed and free connectors (modular plugs and jacks) shall comply with the reliability requirements of the applicable standard specified in Table C.2.

Table C.2 – Standards for free and fixed connectors (modular plugs and jacks)

Category and type	Standard
Category 3, unscreened	IEC 60603-7
Category 3, screened	IEC 60603-7-1
Category 5, unscreened	IEC 60603-7-2
Category 5, screened	IEC 60603-7-3
Category 6, unscreened	IEC 60603-7-4
Category 6, screened	IEC 60603-7-5
Category 6_A, unscreened	IEC 60603-7-41
Category 6_A, screened	IEC 60603-7-51
Category 7, screened	IEC 60603-7-7
Category 7_A, screened	IEC 60603-7-71, IEC 61076-3-104 or IEC 61076-3-110 as appropriate

The default criteria and conditions in the relevant standards in Table C.2 apply, except as specified in the remainder of this clause.

The number of mating cycles (insertions and withdrawals) for free and fixed connectors (modular plugs and jacks), and the number of conductor re-terminations per solderless connection shall comply with the specifications in Table C.3.

Table C.3 – Free and fixed connectors (modular plugs and jacks) operations matrix

Connecting hardware type	Insertion and withdrawal, and conductor re-termination, operations	Minimum number of operations
Free connector (modular plug)	Insertion / withdrawal with fixed connector (modular jack)	750
	Cable re-termination	0
Fixed connector (modular jack)	Insertion / withdrawal with free connector (modular plug)	750
	Cable re-termination	20 [a, b]

[a] Unless not intended for re-termination, in which case this value equals 0.

[b] The range of conductor size and type shall be in accordance with the manufacturer's instructions.

Between terminations, the solderless connection should be inspected for debris and extraneous material should be removed.

C.4 Other connecting hardware

Examples of other connecting hardware include:

- cross-connect blocks and plugs;
- pin and socket connectors.

The reliability of connecting hardware, other than free and fixed connectors (modular plugs and jacks), shall be demonstrated by complying with the applicable requirements of the standards specified in Table C.4. The connecting hardware shall be terminated, mounted, and operated in accordance with the manufacturer's instructions for use. A minimum of 100 individual electrical contact paths (e.g. connecting hardware, input to output) shall be tested without failure.

The following tests shall be as per the manufacturer's specification:

- examination of dimensions and mass;
- insertion and withdrawal force requirements;
- effectiveness of any connector coupling device requirements;
- gauging and gauging continuity requirements;
- arrangement for contact resistance test;
- arrangement for vibration (dynamic stress) test.

Table C.4 – Reference for reliability testing of other connecting hardware

Category and type	Standard	
All Categories, unscreened	IEC 60603-7	Clause 6 and Clause 7 [a]
All Categories, screened	IEC 60603-7 and IEC 60603-7-1	

[a] Excluding subclauses addressing pin and pair grouping assignment, creepage and clearance distances, transmission characteristics, transfer impedance, and test group EP (transmission testing).

The default criteria and conditions in the relevant standards in Table C.4 apply, unless otherwise specified in this clause.

The number of mating cycles (insertions and withdrawals) for other connecting hardware, and the number of conductor re-terminations per solderless connection shall comply with the specifications in Table C.5.

Table C.5 – Other connecting hardware operations matrix

Connecting hardware type	Insertion and withdrawal, and conductor re-termination, operations	Minimum number of operations
Other connecting hardware “free connector”	Insertion / withdrawal operations with “fixed connector”	200
	Cable re-termination	0
Other connecting hardware “fixed connector”	Insertion / withdrawal operations with “free connector”	200
	Cable re-termination	20 [a, b]
	Jumper re-termination	200

[a] Unless not intended for re-termination, in which case this value equals 0.

[b] The range of conductor size and type shall be in accordance with the manufacturer's instructions.

Between terminations, the solderless connection should be inspected for debris and extraneous material should be removed.

Annex D
(informative)

Electromagnetic characteristics

Cabling consists of passive components and can therefore only be verified for conformance to electromagnetic compliance (CISPR 22 and CISPR 24) when attached to application specific equipment. However, electromagnetic characteristics of a network installation are influenced by parameters, such as the balance and/or screening properties of the cabling.

Balance is characterised by unbalance attenuation, i.e. the ratio between the unwanted common mode signal power and the injected differential mode signal power. This common mode signal which arises from imperfections in the cabling system, such as asymmetry, causes electromagnetic emission and affects noise immunity. Unbalance attenuation is characterised for components, including cables and connecting hardware. Limits for unbalance attenuation are also given for cabling. Unbalance attenuation test methods for components are well established for frequencies up to 100 MHz.

Screening effectiveness is characterised for components including cables, connecting hardware and patch cords. At frequencies up to about 30 MHz, the effectiveness of component screening can be characterised by transfer impedance. Transfer impedance is the ratio of the longitudinal voltage developed on the secondary side of a screen to the current flowing in the screen. This unwanted current causes radiation and affects immunity. At higher frequencies screening effectiveness may be characterised by screening attenuation, i.e. the ratio between the common mode signal in the conductors enclosed in the screen and the radiated signal outside the screen.

Balance and screening effectiveness properties may be combined in one parameter, coupling attenuation, which is the ratio between the wanted signal power and the unwanted radiated power from the cabling. Coupling attenuation is normally measured from 30 MHz to 1 000 MHz.

Coupling attenuation can be applied to screened and unscreened cables, connecting hardware and cabling.

Test methods and requirements for components have been developed. Characterisation of coupling attenuation for cabling is a subject for further study.

Use of components with good electromagnetic characteristics, the use of screened or unscreened components throughout a system, and installation according to manufacturers' instructions, will help to achieve good electromagnetic characteristics of the cabling.

The electromagnetic characteristics of the components referenced in this standard may be used for guidance when application specific electronic equipment is constructed, and tested for compliance with CISPR 22 and CISPR 24. The relationship between the CISPR requirements and these characteristics is a subject for further study.

Annex E
(informative)

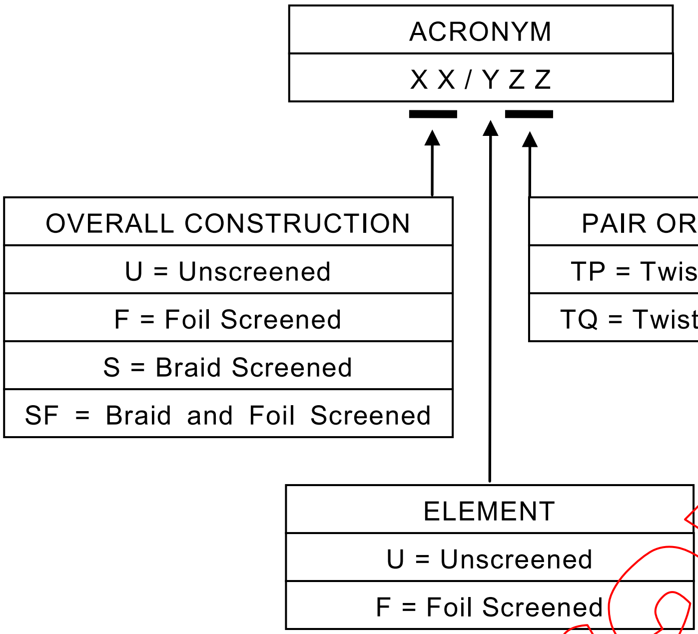
Acronyms for balanced cables

There is a great variety of cable constructions and a number of systems to describe these constructions in a shortened form. These abbreviations have been used to describe the difference in construction as well the difference in impedance. Since such acronyms are used in many commercial documents and have never been clearly specified by a standard, the same term could mean different kinds of constructions in different contexts.

The intention of this annex is to clarify this situation and give guidance on how to use abbreviations for the main constructions used for communication cables. This document uses the words balanced cable, unscreened/screened cable and unscreened/screened cable element for the cable constructions described in this annex.

To reduce confusion, a more systematic naming is specified in Figure E.1. It is understood that cable names based on this schema only describe the types of constructions and not any transmission characteristics such as impedance. All screened cables, whether individually or overall, foiled, braided or both, require matching connecting hardware capable of handling all of the screens involved.

Figure E.2 gives examples of cable constructions and their names based on this schema.



For example:

U/UTP = overall unscreened cable with unscreened twisted pairs (often referred to as UTP)

F/UTP = overall screened cable with unscreened twisted pairs (often referred to as FTP)

S/FTP = overall braid screened cable with foil screened twisted pairs (often referred to as STP or PiMF)

SF/UTP = overall braid and foil screened cable with unscreened twisted pairs

Figure E.1 – Cable naming schema

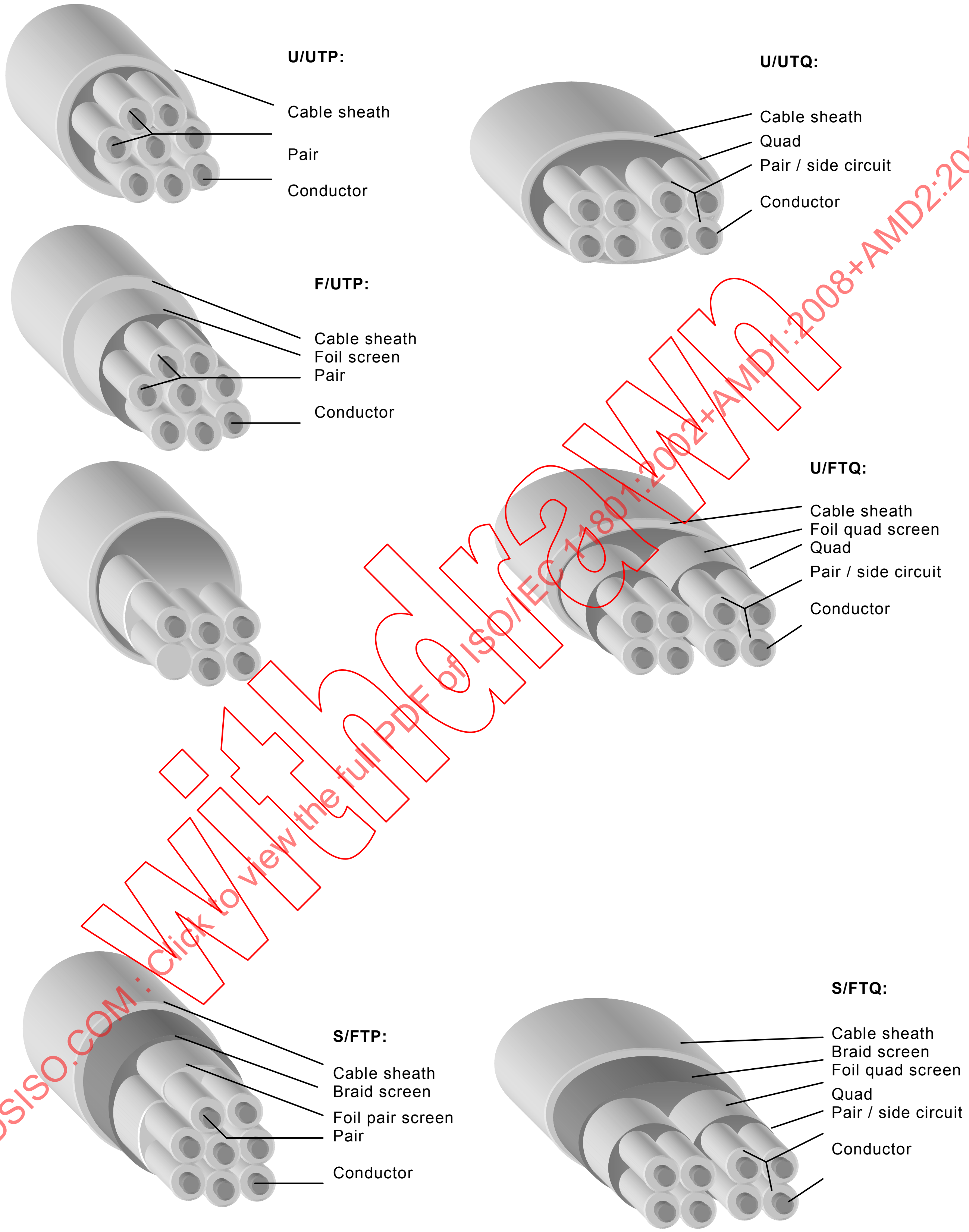


Figure E.2 – Examples of cable types

Annex F
(informative)

Supported applications

F.1 Supported applications for balanced cabling

Balanced cabling specified in this International Standard is intended to support the applications detailed in this Annex. Other applications, not listed, may be supported too.

Balanced cabling applications are matched to channel performance classes specified in Clause 6 of this standard. Generic cabling has been designed to support optical and electrically balanced transmission. Applications using unbalanced transmission are outside the scope of this standard.

Table F.1 contains applications with mature or technically stable international specifications (for example, published ITU recommendations, ATM Forum specifications or ISO/IEC standards or at least DIS status at ISO/IEC).

Table F.1 – Applications using balanced cabling

Application	Specification reference	Date	Additional name / reference
Class A (defined up to 0,1 MHz)			
PBX	National requirements		
X.21	ITU-T Rec. X.21	1992	
V.11	ITU-T Rec. X.21	1996	
Class B (defined up to 1 MHz)			
S0-Bus (extended)	ITU-T Rec. I.430	1993	ISDN Basic Access (Physical Layer)
S0 Point-to-Point	ITU-T Rec. I.430	1993	ISD2 Basic Access (Physical Layer)
S1/S2	ITU-T Rec. I.431	1993	ISDN Primary Access (Physical Layer)
Class C (defined up to 16 MHz)			
Ethernet 10BASE-T	IEEE 802.3, Clause 14 [a]	2005	CSMA/CD IEEE 802.3i
Token Ring 4 Mbit/s	ISO/IEC 8802-5	1998	
ATM LAN 25,60 Mbit/s	ATM Forum af-phy-0040.000	1995	ATM-25/Category 3
ATM LAN 51,84 Mbit/s	ATM Forum af-phy-0018.000	1994	ATM-52/Category 3
ATM LAN 155,52 Mbit/s	ATM Forum af-phy-0047.000	1995	ATM-155/Category 3
Class D 1995 (defined up to 100 MHz)			
Token Ring 16 Mbit/s	ISO/IEC 8802-5	1998	IEEE 802.5:1998
ATM LAN 155,52 Mbit/s	ATM Forum af-phy-0015.000	1994	ATM-155/Category 5
Ethernet 100BASE-TX [a,b]	IEEE 802.3, Clause 25 [a]	2005	Fast Ethernet IEEE 802.3u
Token Ring 100 Mbit/s	IEEE 8802-5t	2000	
PoE	IEEE 802.3 af	2005	Power over Ethernet, IEEE 802.3af
Class D 2002 (defined up to 100 MHz)			
Ethernet 1000BASE-T	IEEE 802.3, Clause 40 [a]	2005	Gigabit Ethernet, IEEE 802.3ab
Fibre Channel 1 Gbit/s	ISO/IEC 14165-115	2007	Twisted-pair Fibre Channel 1G
Firewire 100 Mbit/s	IEEE 1394b	2002	Firewire/Category 5
PoE+	IEEE 802.3 at [b]	2009	Power over Ethernet Plus
Class E 2002 (defined up to 250 MHz)			
ATM LAN 1,2 Gbit/s	ATM Forum af-phy-0162.000	2001	ATM-1 200/Category 6
Class E_A 2008 (defined up to 500 MHz)			
Ethernet 10GBASE-T	IEEE 802.3, Clause 44	2006	10Gigabit Ethernet, IEEE 802.3an
Fibre Channel 2 Gbit/s	INCITS 435	2007	Twisted-pair Fibre Channel 2G-FCBASE-T
Fibre Channel 4 Gbit/s	INCITS 435	2007	Twisted-pair Fibre Channel 4G-FCBASE-T
Class F 2002 (defined up to 600 MHz)			
FC 100 MByte/s	ISO/IEC 14165-114	2005	FC-100-DF-EL-S
Class F_A 2008 (defined up to 1 000 MHz)			

[a] Including support for remote power feeding defined by IEEE 802.3af:2003 and IEEE 802.3at:2009.

[b] For channels used to support applications requiring remote power, see ISO/IEC TR 29125.